Alternative frameworks for the development of mathematics teacher knowledge

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Abstract

Professional development of teachers has been identified as a key area for future curriculum action. This paper examines the present context for professional development and reports on perceived inadequacies within this area of mathematics education. Certain key influences on the evolution of professional development models are identified, and these are illustrated with reference to a number of recent studies into the provision of inservice to teachers and other teacher knowledge base development activities. Alternative models for professional development are canvassed. The paper concludes with a proposed general structure for models of mathematics teacher development (transmissionist models versus meaning-centred models). This structure relates the process of teacher development to assumptions made about the nature of learning and teaching mathematics, and assumptions and beliefs about teacher knowledge.

Background

Teacher development has come to the fore in the last decade as being of crucial importance to the enhancement of mathematics education. Reports at both national and state levels have identified the ongoing development of teacher knowledge as being an area of need. For instance, in Australia, the *Discipline Review of Teacher Education in Mathematics and Science* (DEET, 1989) expressed the view that "there is a pressing need to revise and upgrade both pre-service and post-initial provision to meet the current and future needs of Australian society". Likewise, in Queensland, the recent *Review of the Queensland School Curriculum: Shaping the Future* (Department of Education, 1994), identified the need to upgrade the knowledge base of current teachers and recommended the "creation of collaborative partnerships between teacher education faculties and schools and systems". With reference to another recent curriculum reform in Queensland, Peckman, Robinson, and Underwood (1992) have reported that there is recognition within the teaching profession itself regarding the high value of professional development in the context of the implementation of new mathematics syllabuses.

Mathematics teacher professional bodies have also vigorously emphasised the growing importance of teacher development. The Australian Association of Mathematics Teachers, for instance, in its *National Statement on Girls and Mathematics* (AAMT, 1990) noted that there is a significant role for professional development in the area of gender equity within the life of the mathematics classroom. The *Professional Standards for the Teaching of Mathematics* (1991), published by the National Council for the Teachers of Mathematics (USA) has also argued that "teachers' growth requires commitment to professional development aimed at improving their teaching on the basis of increased experience, new knowledge, and awareness of education reforms".

Sitting against these reports and recommendations, however, is the growingly uncomfortable fact that teacher development as it currently exists in the field is not usually regarded by

teachers themselves as generally being effective in improving the quality of professional practice in mathematics education. For instance, Swinson (1993) found in a survey of teachers drawn from a random sample of 31 Queensland High Schools that only 62% of these had attended an inservice meeting in the previous year, and that only 27% of these judged that they had derived any significant benefit from their attendance. Kanes and Nisbet (1994), in a study focussing on teacher knowledge bases, reported similar findings, and concluded that current inservice arrangements poorly served the needs of mathematics teachers in Queensland. Further, studies such as Bishop and Larkin (1994) have shown that important needs for professional development, such as for regular classroom teachers of NESB students, are at present substantially unmet. Arising from these observations it becomes apparent that new models for the provision of teacher development are needed. A purpose of this paper is to investigate the state of the literature regarding such developments. The paper will first identify the general influences acting on recent research in this area and then explore recent literature in greater detail. The paper will conclude with a conceptual structure for exploring the variety of developments identified.

Influences on professional development models

Programs for the professional development of mathematics teachers, like mathematics teaching itself, are exposed to influences from both within the discipline and more general currents affecting the ethos of education in Australia. Three examples are discussed below: developments in mathematics learning theory, associated epistemological reconceptualisations, and the nature of educational change within institutions teaching mathematics.

Constructivist learning theory

Arguably the most significant contemporary influence on mathematics teaching has been the development of contructivist learning theory (Ernest, 1991; Cobb et al, 1992). This has allowed attention to be focussed on the needs of students rather than on the concepts and processes of standardised teaching practice. The learning aspirations of students historically marginalised by traditional teaching practice can, or so it is claimed, be addressed by teaching processes developed on its learner-centred tenets (AAMT, 1991). Interestingly, this development has been considered favourable not only by those who espouse a social justice agenda, but also by significant sections within the economic rationalist reform movement. Perhaps this is nowhere more clear than in the *National Statement on Mathematics for Australian Schools* (1991) in which concerns for social justice are realised within an explicitly outcomes-based curriculum structure. Constructivism, or as the *Statement* puts it "how students best learn mathematics", is used as the glue bonding otherwise conflicting purposes. Leaving aside the question of how constructivism has been coopted into the political contest surrounding the mathematics curriculum, an issue this paper seeks to highlight concerns the implications of contructivist learning theory for the nature and provision of professional development itself.

In order to proceed with this question it is clear two further developments relevant mathematics education need to be mentioned.

Epistemology

Firstly, talk of the active construction of knowledge has highlighted, for those engaged in mathematics teaching, historic problems to do with the nature of theoretical knowledge generally, and mathematical knowledge in particular. In recent years it has become possible to doubt the formerly predominant claims of educators and practitioners of mathematics concerning the supposedly

objective nature of mathematics knowledge (Walkerdine, 1988; Cobb et al, 1992). Realism within mathematics education has certainly been challenged as the universally preferred epistemology of modern education. Alternatives such as the neo-pragmatism of social contructivists such as Cobb and others, or the knowledge/power relations inscribed within discursive boundaries proposed by post-Foucauldean theorists such as Walkerdine and others offer the contemporary investigator a range of alternative epistemological habitations. Implications for the curriculum of these modern epistemological developments are enormous, and are withou doubt already influencing the shape of educational practice. It might be fair to say, however, that the professional development of teachers has not to date been greatly influenced by these developments. Reasons suggested for this might include the inherent conservatism of mathematics teaching and teacher education (Piaget's Stage Theory, although of doubtful contemporary significance is still routinely 'taught' to pre-service teachers, whereas references to the constructivist foundations of Piagetian theory are usually underplayed). Further reasons for the slow impact of epistemological reassessment of mathematics on mathematics education may relate to difficulties of teacher educators who are faced with the task of operationalising the practical implications of their own theoretical and research driven pursuits. This paper wishes to canvass attempts to develop models for teacher development which accurately relate to alternative epistemological frameworks.

However, not all considerations concerning the nature of knowledge in mathematics education have operated at the fundamental levels indicated above. For instance, Lee Shulman's influential work (1986, 1987) on the constitution of teacher knowledge has allowed for a comprehensive dissection of what knowledge types characterise good teaching within any specific discipline area. Briefly, his typology for teacher knowledge applied to mathematics teaching consists of mathematics content knowledge (mathematics itself), generic pedagogic knowledge (general knowledge of how to teach), pedagogic content knowledge (knowledge of how to teach specific mathematics concepts and processes), etc. His work has been significant in that it allows issues relating to the degree of transfer between general and specific contexts for mathematical knowledge and its instruction to be raised and problematised.

Educational change

A second contemporary development in education relevant to recent progress in thinking within mathematic education has been perspectives deriving from the education change literature (Fullan, 1991a, 1991b; Ruduck, 1991). Fullan (1991a), for instance, argues that the professional development of teachers must be fully identified with the processes of change within an institutional context. Furthermore, a critical component of any professional development element must be the degree to which "individuals can achieve meaning [for any given or evolving workplace innovation] in their own minds". Individual construction of meaning, once it has been subjected to the social processes of negotiation, discussion, and debate, becomes for Fullan a necessary condition for effective professional development. In emphasising the importance of the joint production of meaning, Fullan is moving in a direction convergent with those, such as Schön (1987) and Zeichner (1987), who espouse a doctrine of reflectivity as a condition for successful development of a practitioner's knowledge base. On the epistemological plane, parallels with developments inspired by action research interventions can also be drawn.

Models for teacher development

As we noted above, Fullan has suggested that professional development and educational change belong to an identical set of interactive processes. Chief amongst these he argues is the joint production of meaning involving the ongoing processes of debate, negotiation, experimentation, and inquiry. It has seemed to us that this suggestion offers a good starting point for investigating critical aspects of practices characteristic of alternative professional development schemes. For instance, the question arises as to what tacit theory of learning is implied in a given approach to professsional development. In considering this question, we have found it possible to group the frameworks found in the literature and in current practice into two general classes of models for professional development. The first, the class of transmissionist models, tend to rest on traditional theories of learning and teaching mathematics; the second, meaning-centred models, tend to presuppose that the learner is actively engaged in the processes of constructing viable meanings within the frameworks established by the teacher/facilitator.

Transmissionist models for teacher development

Characteristic of this category of teacher development is the largely passive positioning of mathematics teachers with respect to the processes they encounter within the development programs. Whilst teachers are frequently consulted about the issues and topics of concern to them, once these have been determined, little further reference to teachers is made. Indeed, it may be doubted to what extent information relating to teacher nominated needs (eg Peckman and Robinson, 1992) is taken account of in the establishment of teacher development programs. Teachers, therefore, are involved only at the most general level in identifying needs for development. They are seldom consulted concerning the processes whereby their needs may be met. For instance, notwithstanding attempts to the contrary (Hollingsworth and Robinson, 1993; Australian Association of Mathematics Teachers, 1994), professional development kits all too frequently presuppose the directions and parameters of teachers needs and interests. Inservice seminars and professional conferences etc likewise usually operate within tightly controlled agendas thus limiting the degree of teacher involvement in the process of generating socially powerful meanings for the knowledge presented by experts and applying this to their own situations.

Meaning-centred models for teacher development

Barnett and Tyson (1993) describe the use of case methods to enhance the quality of mathematics teacher knowledge and capacity for autonomous action. This method consisted of discussions between teachers concerning a number of actual teaching situations. Led by a facilitator, the teachers were asked to clarify and elaborate their ideas, justify their positions, and critically examine alternative perspectives. In their findings, the authors report that the processes of negotiation, debate, and joint investigation, led to a deepening of teachers' shared understanding of mathematical content knowledge, as well as the problems and tasks of teaching particular content material (pedagogic content knowledge). Meaningful activity lay at the heart of this professional development strategy. Knowledge relating to mathematical concepts and processes as well as how to teach these was locally produced and maintained. No strong division existed between the theory and practice of knowledge relating to the teaching mathematics. Moreover, teachers in this situation are more likely to view mathematics as "fallible, changing, and like any other body of knowledge, the product of human invention" (Ernest, 1991).

Redden and Pegg (1993) reported case studies relating to the professional

development of teachers which emphasised the importance of the joint identification of needs and production of shared understandings of the problems facing the mathematics teaching staff. One important conclusion in this study was that time spent carefully identifying the issue is crucial in developing a greater understanding of the issue to be addressed. Premature movement to the implementation phase of teacher development is to be avoided.

Clarke and Hollingsworth (1994) have investigated models for professional development and characterised alternative conceptions of teacher change. We have found that these may broadly be grouped into transmissionist and meaning-centred categories. Change as training, and change as systemic restructuring would be examples of transmissionist type models; change as personal development, and change as local reform would give rise to meaning-centred models in the terms we have discussed above.

Clarke and Peter (1993) have presented a comprehensive model in order to capture the interdependence of four elements characteristic of professional development processes. These are identified as: teacher knowledge and beliefs, classroom experimentation, systems of value which interrelate these, and the external agents and instruments of change. The model developed by these authors generates a framework in which transmissionist and meaning -centred models can be conceptualised. Alternative views concerning learning theory, the nature of knowledge in classroom processes, and the values and beliefs supporting these are encompassed within an single framework.

Towards a general structure for models of mathematics teacher development

As suggested by the material presented above, models for teacher development alternate with respect to their differing perspectives on the nature of learning and teaching in mathematics and education. "Transmissionist" models for teacher development tend to espouse transmissionist views concerning the nature of mathematics teaching; whereas "meaning-centred" models for professional development tend to assume that students learn mathematics best in circumstances which encourage the rich development of meaning for mathematical concepts and procedures. Moreover, these alternative model types depend on alternative views concerning the nature of mathematical knowledge itself. The table set out below represents our attempt to highlight the pertinent differences as we see them. Of significance is the correspondence existing between alternative models for teacher development and the views each expressed concerning the nature of student learning in mathematics, teaching, and mathematical knowledge. Appropriate correspondences can also noted relating to the epistemological beliefs and values underpinning the beliefs of the alternate types of models for teacher development. See Table 1. Further research may usefully explore these matters.

Table 1: Generic structure for models of mathematics teacher development

	Transmissionist models	Meaning-centred models
Indicative processes of model type	Knowledge from experts handed to teacher; codifying and classifying conceptual knowledge; greater emphasis and value given to conceptual rather than procedural knowledge; generalised dissemination of concepts and procedures; distinction between theory and practice maintained	Teacher knowledge developed jointly among teachers, resource personnel, researchers and other stake holders; conceptual and procedural knowledge types tend to be valued more equally; local facilitation and production of teacher knowledge; no strong division between the theory and practice of mathematical teaching knowledge
View of mathematics learning embedded in model	Students are positioned as passive targets for instruction	Students are positioned as active players in the multiple tasks of constructing meaningful knowledge
View of mathematics teaching embedded in model	Programmatic teaching directed by external instruments rather than the learning needs of students; means-end; content driven; teacher-centred, predominant focus on the acquisition and maintenance of specific skills, however these tend to be derived from relatively *ad hoc* assumptions; assessment is viewed as an objective and technical procedure to evaluate learning outcomes	Socially interactive; focuses on the development of communication; processes are ranked equally with content outcomes; assessment is to inform learning as well as provide information concerning outcomes
View of mathematics content knowledge embedded in model	Mathematics seen as objectively determined; radically independent of situation eg culture, gender, socio-economic positioning	Mathematics seen as highly situated; objectivity is linked to concepts relating to the social organisation of knowledge; mathematical validity linked to concepts of efficacy rather than abstracted 'correctness'
View of mathematics pedagogic knowledge embedded in model	Knowledge of mathematics teaching reliant upon tradition rather than the emergent needs of students; teaching approach often highly idiosyncratic and not subject to discussion with teaching peers; approaches to teaching transmitted mainly by interactions among teachers and other 'experts'; organised by external influences (eg text books) and external agents (eg official requirements);	Knowledge of mathematics teaching directly related to the emergent needs of the learners; knowledge emphasises and values both concepts and processes of teaching; attention given to pedagogic content knowledge in order to facilitate student learning, rather than general pedagogic knowledge used to augment the general knowledge base of teachers

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