INQUIRY AS A PERVASIVE PEDAGOGIC PROCESS IN MATHEMATICS EDUCATION DEVELOPMENT

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This paper takes up notions of exploration, investigation and inquiry which have played an important part in developing teaching in mathematics over several decades. It recognises theory and research relating to the use of investigational work and inquiry in mathematical learning in classrooms and traces theoretical perspectives relating to inquiry approaches in mathematical learning and teaching development, including constructivism, sociocultural theories, and communities of inquiry. The notion of critical intelligence is introduced to characterise the critical stance taken by teachers in communities of inquiry, and to highlight a dialectic between individual and social forms of learning in mathematics and mathematics teaching. A final section on teachers researching teaching suggests the importance of links between teachers and educators in sustaining inquiry into teaching.

The Inquiry Movement and its Origins

Collaborative research or inquiry approaches are seen as particularly fruitful for mathematics teaching development in a number of parts of the world as is being demonstrated through their debate in international conferences in Europe and more widely (e.g., Krainer, et al, 1999; Lin and Cooney, 2001, Wood, et al, 2001). In the UK, inquiry (seeking to know through creative exploration) as opposed to discovery (trying to find out what *is*) developed from the work of Stenhouse in the Humanities Research Project and Ford Teaching Project (e.g., Elliott and Adelman, 1975). From such projects, over three decades, teachers across the curriculum, started to inquire into classroom processes and practices, establishing the action research movement (Stenhouse, 1984; McNiff, 1988; Elliot 1991). *Action research* formalizes such inquiry approaches to understanding learning and teaching in classrooms.

Meanwhile, also in the UK, the *Cockcroft* Report, from a government inquiry into the teaching of mathematics in schools, emphasized the importance of problem solving and investigational work in a range of teaching approaches that included discussion between teacher and pupils, and pupils themselves, and appropriate practical work (DES, 1982, para. 243 ff). The use of inquiry (or investigation, or exploration) in mathematics teaching had been reflected particularly in a seminal book by Banwell, Saunders and Tahta (1972) which set the scene for inquiry in UK classrooms by offering a range of activities as 'starting points'. Teachers' writing about their experiences of engaging students in investigational activities may be found in issues of the journal *Mathematics Teaching* (see for example issues 71, 73, 75 in 1975 and 1976). Such writings may be seen as early manifestations of teachers' engagement in classroom research into ways in which mathematical exploration can lead to students' conceptual learning of mathematics. Ruthven (2001) speaks of them as "a form of "popular research" involving careful observation of exemplary cases and systematic reflection on them" (p. 173).

'Research' and 'inquiry' can be seen as closely related on a formality continuum where *inquiry* usually implies less formality than is expected of *research*.

The origins of investigational work in mathematics classrooms can be seen as part of an international movement in mathematics learning and teaching in the 1970s and 1980s that promoted conjecturing classrooms and problem-solving environments in the learning of mathematics (Polya, 1945; Mason et al, 1982; Schoenfeld, 1985). Emphasis was largely on processes and heuristics of mathematical problem solving. In the USA, researchers have devised teaching experiments to create and investigate 'inquiry classrooms' (e.g., Davis, Maher and Noddings, 1990), in the UK investigative approaches to learning and teaching mathematics have been studied and characterized (Jaworski, 1994), and in Portugal links are drawn between investigating in mathematics and investigating in developing the teaching of mathematics (Ponte, 2001). Thus we see, internationally, links emerging between inquiry in mathematics and inquiry into the learning and teaching of mathematics.

Knowledge Growth Through Inquiry

Collins (1988) speaks of 'Inquiry Teaching' as engaging the student in "using knowledge, so that it does not become 'inert' knowledge like much of the wisdom received from books and lectures". John Dewey wrote "… no such thing as imposition of truth from without, is possible. All depends upon the activity which the mind itself undergoes in responding to what is presented from without" (Dewey, 1902/90 p. 209)

The notion of inquiry relates particularly to perspectives in mathematics education dealing with cognition and 'construction' of mathematical knowledge. Constructivism might be seen as describing cognitive activity in which individuals through processes of accommodation and reflective abstraction develop and modify mental schemata as their representations of knowledge (Piaget, 1950). Inquiry, or investigative methods in mathematics teaching are seen to fit with a constructivist view of knowledge and learning as they offer challenges to stimulate mathematical thinking and create opportunities for critical reflection on mathematical understanding (von Glasersfeld, 1984; Cobb, et al, 1990; Jaworski, 1994). Through interactions, physical and social, in the world around them, causing challenge to and reorganization of existing mental formulations, learners are seen to develop *conceptual*, *relational* and *principled* understandings of mathematics (Skemp, 1976). In other words, through inquiry, learners go beyond the use and application of algorithms and rules to develop understandings of *general* relationships in mathematics and to deal with problematic aspects of the *abstraction* and *formalism* that is central to mathematics (Nardi, 1996).

Educators and researchers working with teachers have developed constructivist-based models to explain and guide developments in teachers' thinking (e.g., Carpenter, et al, 1988; Cobb *et al.*, 1990; Schifter and Fosnot, 1993; Jaworski, et al, 1999). Theories suggest that teachers will develop *conceptual*, *relational* and *principled*

understandings of *teaching* that enable mathematical development in classrooms. Researchers and theorists, acknowledging the importance of communication and interaction and their resulting discourses to growth of knowledge in teaching have appended the word *social* to *constructivist*, emphasizing the importance of language and discourse in communicative environments through which learning occurs. *Discussion*, *negotiation* and *argumentation* in inquiry and investigation practices are seen to underpin knowledge growth in teaching and in teacher education (e.g., Lampert, 1998; Cobb and Bowers, 1999; Wood, 1999).

Although these theoretical positions recognize the importance of social interactions in promoting growth of knowledge, they are challenged as prioritizing the individual learner rather than attending to the wider picture of learning in classrooms. Researchers and theorists working in Vygotskian traditions locate learning centrally in the sociocultural environment where individual learning is regarded as derivative of social learning (Vygotsky, 1978). Seeing learning as a process of social enculturation with the individual internalizing knowledge from interactions in the social world (Bartolini-Bussi, 1994; Lerman, 1996) is believed to account better for pathological social circumstances that result in learners' alienation from schooling (Lerman, 2000).

In a special issue of *Educational Studies in Mathematics*, devoted explicitly to contrasting individual and social perspectives (Kieran et al, 2001), authors take *discourse* and *communication* as the basis of their analysis of classroom situations involving mathematical learning where "the focus is on the change generated by interpersonal interactions" which "results in a picture which is more complex and closer to life than in the traditional cognitivist studies" (p. 7). Such perspectives emphasize a concept of 'community' and it is through community that we can see some possible rationalization with notions of inquiry.

Communities of Inquiry

Schoenfeld (1996) described *a community of inquiry* that developed in his mathematics education research group in a university environment. Researchers in the group were engaged fundamentally in inquiry. Interactions within the group led to questioning and critiquing individual perspectives in a mutually supportive fashion so that relationships were strengthened, a clearer understanding of inquiry, reflection and critique emerged, and knowledge of mathematics learning and teaching developed.

The term 'Communities of Inquiry' is used by Gordon Wells (1999) in a discussion of 'dialogic inquiry' rooted in the work of Vygotsky. Wells draws on notions of inquiry as "a willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them", and as a means to emphasize "the essential continuity of education (Dewey, 1938, 1956)". This continuity is shown through the use of inquiry by students in classrooms, teachers responsible for their education, and those who are responsible for teachers' initial

preparation and continuing professional development (Wells, 1999, p. 122). Wells draws on interpretations of *community* by a number of authors including Rogoff (1994) and Lave and Wenger (1991). He distinguishes communities of inquiry from communities of practice by highlighting the importance of "*metaknowing* through reflecting on what is being or has been contributed and on the tools and practices involved in the process" (p. 124; my emphasis). Wells' research focuses on teachers who are "attempting to develop such communities of inquiry and simultaneously making their attempts the objects of their own inquiries" (p. 124). This linkage between inquiry as a pedagogical tool, and inquiry into the use of this tool to promote learning in highlighted by Chaiklin, who writes, "Social science research has the potential to illuminate and clarify the practices we are studying as well as the possibility to be incorporated into the very practices being investigated. (1993, p. 394). His words emphasize the nature of research, not only as a means to illuminate practice but as a source of study in investigations of practice; the research itself being part of the practice under investigation. Both Wells and Chaiklin thus point to a community of inquiry as involving a reflexive relationship between a community of practice and its activities in inquiring into and developing practice.

Cochran Smith and Lytle (1999), referring to a conceptual framework for teachers' learning emanating from a three-year study of the relationships of inquiry, knowledge and professional practice in urban communities in the U.S., introduce as a new construct 'inquiry as stance'. They use this construct to describe "the positions teachers and others who work together in inquiry communities take towards knowledge and its relationships to practice" (p. 288). They write "Teachers and student teachers who take an inquiry stance work within inquiry communities to generate local knowledge, envision and theorize their practice, and interpret and interrogate the theory and research of others" (p. 289). Teachers taking an inquiry stance "[raise] questions about what counts as teaching and learning in classrooms" and "critique and seek to alter" systemic norms and relationships.

Inquiry and Critical Reflection or Intelligence

In a community of inquiry, the novice practitioner is drawn into the community through processes of observation, practice, questioning of practices, and inquiry into practice, as indicated in Schoenfeld's (1996) example. Wells (1999) emphasizes the importance of *collaboration* between teachers and researchers in investigating ways of improving practice. At the root of such a model is the belief in a critical mode of reflective practice in which the roots of social engagement are challenged so that practices are continuously reconceptualized and developed for the benefit of participants. Cochran Smith and Lytle (1999, p. 289) suggest that "the work of inquiry communities is both social and political", aiming to bring about change in traditional ideas of knowledge and develop richer conceptions of practice.

Such a model is dialectical in its conceptualization as an individual or social process. It is a social process in the sense that a participant is a member of a community (e.g. of teachers) with its own practices and dynamics of practice which go through social

metamorphoses as inquiry takes place. It is an individual process in that individuals are encouraged to look critically at their own practices and to modify these through their own learning-in-practice. Developments within the community result from rationalisations, implicit and overt, between ongoing practices. Wenger (1998) speaks of "modes of belonging", including *engagement*, *imagination* and *alignment*. We engage with ideas through communicative practice, develop those ideas through exercising imagination and align ourselves, critically, "with respect to a broad and rich picture of the world" (p. 218). It seems possible to conceptualize inquiry learning in these terms.

The notion of *Community of Inquiry* might therefore be seen to draw together elements of (social) constructivism and elements of sociocultural theory: participants grow into and contribute to continual reconstitution of the community through critical reflection; inquiry is developed as one of the norms of practice within the community and individual identity develops through reflective inquiry. This combination can be seen as particularly relevant to the development of teaching through teachers inquiring into their own practices of teaching mathematics. To be sustained, inquiry must be overt to a considerable degree, and it is through individuals and groups making inquiry explicit that critical intelligence develops. Two examples from the UK illustrate these ideas: in a context of 'mentoring' in initial teacher education in mathematics, Jaworski and Watson (1994) contrast the "inner-mentor" of the critically inquiring individual, with processes of "co-mentoring" through which the community or group develops - inner-mentor and co-mentoring are reflexive modes in a process of critical inquiry; secondly, a group of mathematics educators abstracted a model from their own activity in developing teaching, known as *the anecdoting process* (Mathematical Association, 1991). This was based on teachers' stories or anecdotes in a variety of forms, used as a reflective device to promote the raising of issues and addressing of critical questions relating to teaching. Research showed evidence of teachers' critically reflective practice leading to teaching development of individuals and to thinking about teaching development within constituted groups. *Critical intelligence* (a form of 'metaknowing') was seen to result from an increasing awareness of issues that teachers had to face in the processes of developing teaching.

This process of developing critical intelligence can be seen as related to Schön's (1983, 1987) notion of *reflection-in-action* in which teachers recall issues discussed in critical reflection outside the classroom and act consciously in response to events in the classroom. Similarly, in a theory called the *discipline of noticing*, Mason (e.g., 2001) has suggested that critical reflection on past events, in collaboration with colleagues, can lead to *noticing in the moment* in practice, allowing the possibility for alternative decisions and actions.

Thus, theory suggests that teachers' reflective questioning (often in collaboration with colleagues) *outside* the classroom, of practices *in* the classroom (reflecting on action), leads to a more overt in-classroom awareness of issues (reflecting in action)

resulting in corresponding classroom action and, possibly, changes to practice. Questions have been raised about the applicability of such processes or models for teaching development more widely (Eraut, 1994). Although some evidence exists to show that such situations occur (Jaworski, 1994), systematic research is needed to test these ideas and gain further insights to these processes.

Teachers and Educators Researching Teaching

In mathematics education around the world, projects focusing on mathematics teaching development encouraged models of critically reflective practice resulting in the development of communities of inquiry, of critical intelligence within these communities, and examples of teacher action research (ATM, 1987; Zack, Mousley and Breen, 1997). In most cases, those leading such projects found their own thinking and practices developing alongside the teachers and students with whom they worked. For example, in the UK, research showed that *naive* questions from a researcher studying teaching were seen as *hard* questions by teachers and led to teachers critically reviewing their own theories of teaching. A reflexive relationship between researcher and teacher led to each of them examining critically their conceptualizations of teaching and its development (Jaworski, 1994). In Austria, Krainer and colleagues (e.g. Krainer, 1993) developed a university course in which teachers, alongside educators, explored aspects of teaching practice. The resulting inquiry led to developments in practices at all levels. In New Zealand, Britt, Irwin and colleagues (e.g. Britt, *et al*., 1993) worked with teachers from intermediate and secondary schools to enhance teaching through inquiry approaches. Learning at all levels resulted from mutual inquiry. Again in the UK, a project to explore developments in teaching resulting from teachers overt inquiry into their own practice showed teachers accommodating to notions of teacher-research (Jaworski, 1998). As confidence in inquiry approaches developed, teachers gained insights into classroom approaches and ways of developing them that had previously been no more than implicit in their work. Brown and Coles (2000) report a project which saw teacher and students as a community of inquir*ers*, together inquiring into aspects of mathematics and leading to learning for students, teacher and educator.

A consequence that became clear from many of these projects, was that teacher-research was hard to sustain without support or stimulus from externally based colleagues, such as university researchers, or from experienced researchers within a school environment. Thus the importance of communities of inquiry including teachers, educators and researchers is indicated. However, this is not to suggest that educators or external researchers bring with them the knowledge to tackle perceived problems in learning and teaching in classrooms. Many of the reports in JMTE (The Journal of Mathematics Teacher Education[1]) indicate that those initiating and/or researching programmes learn significantly from their involvement in those programmes. Yet, as educators, we do not seem to have clear visions about our activity with teachers to enable the developments about which we speak and write in ultra-sophisticated ways. Like teachers' activity with students in mathematics

classrooms, our activity with teachers in education programmes often stops short of realizing the high ideals we have for learning development. Educators too are practitioners in processes of inquiry leading to tackling the big issues in teaching.

It seems important to end this short version of a much longer paper with the observation that inquiry approaches are no panacea for developing effective learning at any level: by their very nature they do not provide formulaic answers to the problems of learning and teaching. However, in collaborative modes they have been shown as powerful to promote the kinds of thinking that lead to development. It is this notion together with questions about the more widespread implementation of such approaches that I would like to offer in the group at CERME3 for further consideration and debate.

Notes

[1] I can draw on many JMTE articles to illustrate and provide evidence for these remarks, and others in this paper but to do so here would make the paper longer than is acceptable.

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