COLLABORATION, DIALOGUE AND METACOGNITION: THE MATHEMATICS CLASSROOM AS A "COMMUNITY OF PRACTICE"

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This paper presents a theoretical framework for guiding future research whose purpose is to understand how knowledge is constructed and transacted in collaborative and individual activity involving teachers and students. A synthesis of sociocultural and social constructivist theories has contributed to the formulation of our central metaphor of the classroom as a "community of practice". In creating such classrooms, three inter-related contexts need to be considered: teacher-student interaction, student-student interaction and individual reflection. These contexts are examined in terms of three phenomena of interest: collaboration, mathematical dialogue and metacognitive activity.

Recently published Australian mathematics syllabi and curriculum frameworks emphasise that doing mathematics is a situated human activity, and that students learn to think mathematically by constructing, sharing, and critiquing ideas with others. The National Statement on Mathematics for Australian Schools (Australian Education Council, 1991), for example, includes among its goals that students should learn to communicate mathematically, develop their capacity to use mathematics in solving unfamiliar problems individually and collaboratively, and experience the processes through which mathematics develops. Additionally, the Strands of *Mathematical Inquiry* and *Choosing and Using Mathematics* recommend that students develop managerial procedures (that is, metacognitive skills) for making plans, checking progress, and evaluating different strategies for tackling a problem. In Queensland, general objectives within the new Senior Mathematics syllabi (Board of Senior Secondary School Studies, 1992) address communication, applying mathematics in life related situations, and developing logical arguments and justifying conclusions. However, it remains a challenge for researchers and teachers to translate these goals into effective teaching-learning practices.

The approach described here outlines a theoretical framework for understanding and promoting collaborative problem solving, dialogue and metacognitive activity in mathematics classrooms. We provide a working synthesis of sociocultural and social constructivist theories in formulating our central metaphor—the classroom as a community of practice.

The Classroom as a Community of Practice.

The metaphor of the classroom as an active community of mathematics practitioners arises from diverse but related theorising regarding the social context of learning and development. It is conveyed in various terms such as apprenticeship (Collins, Brown and Newman, 1989), legitimate peripheral participation (Lave and Wenger, 1991), acculturation (Resnick, 1989), guided participation (Rogoff, 1990), and with regard to mathematics education it has been exemplified to varying degrees in the work of Schoenfeld (1985, 1992), Lampert (1990) and Cobb and colleagues (Cobb, Wood and Yackel, 1991). Discourse theory (for example Wertsch, 1991), sociocultural theory (Vygotsky, 1978), and social constructivist theories (for example Perret-Clermont, 1980) have contributed to our central metaphor. These theories converge on the view that intellectual activities are in essence social activities involving the adoption of particular forms of language, conventions regarding representations of ideas, methods for resolving differing viewpoints, and procedures for proposing and defending conjectures. To learn mathematics, therefore, is to enter into an ongoing conversation conducted between practitioners who share, in varying degrees, common language and symbolic systems, and an understanding of the conventions and history of the community.

Creating the Conditions for a Community of Practice Classroom.

To create a community of practice classroom three inter-related contexts need to be considered: (i) contexts of teacher-student interaction in which non-traditional roles and expectations are created; (ii) contexts of student-student interaction where students begin to perceive themselves and their peers as reconstructing and creating mathematical ideas; and (iii) contexts of individual reflection where students are given the opportunity to engage in self-directed dialogue and internalise the scaffolded support provided by teacher and peers.

(i) Teacher-student interaction. In traditional classrooms students are expected not so much "to do mathematics", as "to learn about mathematics". As a result, their predominant role in the classroom is passive—observing the teacher demonstrate certain mathematical conventions, and imitating the teacher's performance (Lave, Smith and Butler, 1989). The notion of learning as "entering a community of practitioners" remakes the classroom into the site of mathematical activity engaged in by the students, but with guidance and direction offered by the teacher. In renegotiating the classroom norms for what counts as mathematics, the teacher and students together create an evolving tradition or communal story in which concrete events (for example, making mistakes in front of the class, or searching for words to express an idea) are used as paradigm cases of how mathematics is to be done. The teacher does not explicitly evaluate the students' interpretations and solutions of problems, but engages in a dialogue with them that makes explicit the processes of mathematical thinking. The adoption of an engaged but non-

evaluative role by the teacher seems to be a necessary condition to elicit students' verbalisation of their thinking. In addition, the teacher's role involves building connections between the students' ideas (the local mathematics of the classroom) and the broader field of mathematics. For example, as students report solutions and proofs to their classmates, the teacher may paraphrase and re-present their ideas in another form, or offer them conventional mathematical vocabulary to express their ideas (Lampert, 1990). Recently Steffe (in press) has argued that reflection on the constructive mathematical activity of children ("a second-order construction") is central to the role of mathematics educators. This argument should perhaps be extended to include teachers' use of their reflections to plan new activities that extend and challenge students' current ideas. The recurring cycle of [classroom problem solving activities] → [reflection on the constructive activity of the students] → [planning additional activities contingent on the actual thinking that students displayed] is an instantiation of Vygotsky's (1978) notion of the Zone of Proximal Development, where the teacher's planning and classroom practices are consistently pitched at the growing edge of students' demonstrated competence.

In Table 1 (from Granott, 1993) the intersection of the dimensions (levels of collaboration) x (levels of expertise) is used to elaborate the types of social partnerships that can occur in classrooms. In the traditional classroom, independent activity of the asymmetric type predominates (imitating the teacher). In community of practice classrooms, the goal is to move along the collaboration dimension, so that teacher-student interaction occurs within an **apprenticeship** or **scaffolding** structure. In such asymmetric but collaborative structures, teachers attempt to adopt the perspective of the students, to work with students' ideas, and to gradually transfer dominance in the mathematical exploration and dialogue to the students—in short, to create effective Zones of Proximal Development.

Comparative Expertise	**Independent Activity**	**Moderate Collaboration**	**High Collaboration**
Asymmetric (Teacher-Student)	Imitation	Apprenticeship	Scaffolding
	Swift Imitation	Asymmetric Counterpoint	Asymmetric Collaboration
Symmetric (Student-Student)	Parallel Activity	Symmetric Counterpoint	Mutual Collaboration

Table 1. Social Partnerships in the Classroom

(ii) Student-student interaction. Student-student interaction in community of practice classrooms is characterised by **mutual collaboration** and/or **symmetric counterpoint,** as students jointly attempt to solve problems and use each other as sources of information and sounding-boards for

ideas (see Table 1). In contrast, traditional group work is characterised by students working in parallel, with the main learning process being imitation of the high status and high ability peers (Cohen, 1982; Webb, 1991). It is not surprising that such group work has been found to be ineffective, particularly for less interested and less able students (see Good, Mulryan and McCaslin, 1992).

To create the context for collaborative student interaction, teachers need to guide students toward a set of shared norms that include the following (see Cobb, Wood and Yackel, 1991): *cooperate* to produce mutually acceptable solution methods and interpretations; *persist* and consider alternatives; have the *courage* to propose ideas; *ask for explanations* and evidence when disagreements occur; demand that mathematical solutions be *explainable and justifiable*; and operate as a community of *consensual validators* (establish ways of resolving disputes). This view of peer group interaction contrasts with the Slavin (1991) model and other similar approaches (for example Johnson and Johnson, 1987) where groups are used as a management technique to motivate time on task, and ensure the mastery of facts and procedures. Noddings (1989) described such group work as outcome-oriented, in contrast to the developmental and epistemological concerns of group work derived from social constructivist/sociocultural perspectives.

For mathematical thinking to develop, both teacher-student and student-student interaction are necessary. In asymmetric or teacher-student dialogue, more abstract and general ideas are privileged over experiential and concrete concepts, whereas in symmetric interaction with peers, students are more likely to employ everyday terms and examples, and to tentatively try-out ideas. Nonetheless the two social contexts are connected—in peer collaboration students will begin to incorporate the more mathematical language and forms of representation previously scaffolded by the teacher, and in scaffolded instruction the teacher can use examples and illustrations gained from closely observing the peer interaction.

(iii) Individual reflection. In addition to teacher-student and peer collaboration, the importance of creating contexts which facilitate individual reflection must be acknowledged. This aspect of our approach derives from a central tenet of constructivist theories—namely, that the construction of more equilibrated schemes of knowledge occurs through the reflective and self-regulatory activity of the individual. Individual reflection and self-regulation are **metacognitive processes**; nonetheless, they have a social nature because in order to distance oneself from the activity at hand one must adopt the perspective of an observer—to reflect is to engage in a conversation with oneself. In such a conversation, ideas can be reconsidered in the light of previous joint activity with teachers or peers.

Within a Vygotskian framework, the course of development is characterised by increasing levels of awareness, control, and consciousness of higher intellectual functions such as problem solving and reasoning (see Renshaw, in press; Wertsch, 1985). Central to the emergence of such metacognitive processes is the internalisation of the communicative tool of language. Language has the dual functions of communicating with others and directing one's individual activities and cognitive processes. Such self-directed inner speech facilitates task analysis and monitoring of progress, and also maintains attention, motivation and involvement when difficulties arise (Rohrkemper, 1989).

Directions for Future Research

The previous section described the features of three learning contexts which are present in community of practice classrooms, and conditions for promoting the interdependent processes of collaboration, communication and metacognition. As self-regulation is considered to be a product of communicative dialogue in collaborative social contexts, we focus on the development of **metacognition** as our central interest in identifying directions for future research within our proposed theoretical framework.

Previous research on metacognitive aspects of mathematical thinking has yielded useful insights into students' reflective and self-regulatory processes (for example Goos, 1993; Wong, 1989), but has met with less success in improving their capacity to use these processes. The most promising types of intervention have been of two kinds: the first encourages **individual reflection** (for example, Linn, 1987, on students' use of reflective journals) or **teacher-student interaction** in the form of expert scaffolding (for example, Campione, Brown and Connell, 1989). Schoenfeld's (1985) highly successful work with college students falls into the latter category. The teacher has two central roles in Schoenfeld's approach: creating Zones of Proximal Development by using metacognitive prompts to extend students' self-monitoring (scaffolding as adult guidance); and establishing a mathematical community of practice in which students are expected to explain and justify their assertions to the teacher and to their peers. Failure to address this issue of classroom norms and culture may have contributed to the inability of other researchers to reproduce Schoenfeld's results (for example Johnson and Fischbach, 1992).

Although Schoenfeld's teaching approach includes small group work as a major component, little consideration is given to the processes of **student-student interaction** (scaffolding as collaboration with peers): the questions of *how* students communicate and collaborate to generate new ideas and monitor each other's thinking, and *how* this interaction might be internalised as individual reflection and self-regulation, are left unanswered. Neither is any light shed on these issues by other studies which have investigated small group work in mathematics. For example, many studies have taken a "black box" approach (Good, Mulryan and McCaslin, 1992) by merely examining the relationship between *inputs* (student characteristics, group composition, goal structures) and a narrow range of *outcomes* (achievement in basic skills, or social and affective benefits). A second group of studies has attempted to identify processes which are related to *achievement*; for example, help seeking (Webb, 1991), sociolinguistic characteristics of effective requests for help (Wilkinson, 1985), and the use of process enhancing tasks (Hertz-Lazarowitz, 1989).

The literature on improving *metacognitive* processes via small group work is limited, and has produced conflicting results. One approach which has received some attention involves assigning metacognitive roles. In a recent Australian study, Cooper, Atweh, Baturo and Smith (1993) assigned the roles of Recorder-reporter, Checker, and Decision-maker to six groups of Year 5 students who worked on closed and open problems. These treatment groups were reported to show greater improvement than a similar number of control groups (no role assignment) in problem solving, higher intellectual functioning, metacognitive processes and cooperative behaviour. In contrast, Resnick (1989) reported no success with assigning managerial problem solving roles (planner, director, doer, critic) to groups of Grade 4-7 children. Ross and Raphael (1990) compared the effectiveness of decision making in groups with structured or unstructured task roles, and concluded that role assignment may interfere with learning by decreasing motivation, reducing helping norms, and overemphasising organisational tasks at the expense of learning processes.

It appears that no single study has attempted to implement an approach which addresses all three contexts in which metacognitive abilities may be developed—teacher-student interaction within a community of practice, student-student collaboration, and individual reflection—and how these contexts might be related (see Figure 1). In particular, the interdependent processes of

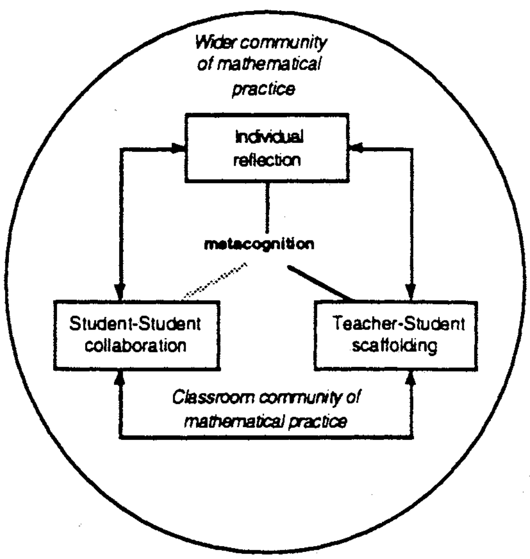

Figure 1.
Developing Metacognitive Processes in Community of Practice Classrooms

collaboration, communication and self (and other) regulation that occur when students interact with their peers are poorly understood. These deserve careful investigation if the potential benefits of future research into small group processes are to be translated into higher quality small group learning.

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