The Role of Pedagogy in Classroom Discourse

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Current curriculum initiatives in mathematics call for the development of classroom communities in which communication about mathematics is a central focus. In these proposals, mathematical discourse involving explanation, argumentation, and defense of mathematical ideas, becomes a defining feature of a quality classroom experience. In this paper we provide a comprehensive and critical review of how mathematics teachers deal with classroom discourse. Synthesising the literature around a number of key themes, we critically assess the kinds of human and material infrastructure that promote mathematical discourse in the classroom and that allow students to achieve desirable outcomes.

Introduction

Classroom mathematical discourse plays a central role in shaping mathematical capability and disposition (Ball, Lubienski, & Mewborn, 2001; Shulman & Shulman, 2004; Stein, 2001). Carpenter, Franke, and Levi (2003) maintain that the very nature of mathematics presupposes that students cannot learn mathematics with understanding without engaging in discussion. Initiatives like Principles and Standards for School Mathematics (PSSM) (National Council of Teachers of Mathematics, 2000) and the Numeracy Development Project (Ministry of Education, 2006) have replaced traditional classrooms by "learners talking to each other, [and] by groups of students voicing their opinions in whole class discussions" (Sfard, Forman, & Kieran, 2001, p. 1). In such classrooms, talking about mathematics becomes acceptable, indeed essential, and mathematical discussion, explanations, and defense of ideas becomes a defining feature of a quality mathematical experience.

In this paper we explore the sorts of pedagogies that, through classroom discourse, contribute to students' active engagement with mathematics. Our starting point is in the acknowledgement that effective classroom discourse is not as easy to implement as is often assumed. Although new initiatives have urged teachers to invite students to "develop explanations, make predictions, debate alternatives approaches to problems … [and] clarify or justify their assertions" (Brophy, 2001, p. 13), implementing such proposals with positive effect is often fraught with problems.

We look at what research has shown about effective classroom discourse and explore how those findings play out within mathematics pedagogy. We do this by critically investigating recent research on quality mathematics classroom pedagogy. Arguably, influences beyond the classroom also have a marked effect on teacher effectiveness and hence on learner outcomes. For example, a number of researchers (see McClain & Cobb, 2004; Millett, Brown, & Askew, 2004) have demonstrated that what is done in classrooms can be attributed in no small way to the human resources provided by others in the school. Other researchers (e.g., Sheldon & Epstein, 2005) have found that effective and sustainable relationships between the home, community, and school, significantly influence classroom teachers' enthusiasm for and success with enhancing learning. Findings, like these, that

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point to shared responsibilities and mutual investment in students' well-being, serve to underwrite our discussion on how teachers deal with classroom discourse in a way that enhances desirable student outcomes.

In reporting on the work undertaken on mathematical discourse we have conceptualised teaching as nested within an evolving network of systems. The system itself functions like an ecology, in which the activities of the students and the teacher, as well as the school community, the home, the processes involving the mandated curriculum, and education-at-large, are constituted mutually through their interactions with each other. From a bottom-up vantage point, the classroom is a central pivot within the system and, in this paper, creates the context for our discussion on discourse.

In the next section we outline the method we used to access our data. We then synthesise the literature, organising the discussion around a number of key themes, through which we critically assess the kinds of human and material infrastructure that allow students to achieve mathematical and social outcomes.

Method of Locating and Assembling Data

In this paper our objective is to report findings from research about communication in mathematics classrooms. Our review looks at research that addresses the following question: What are the characteristics of pedagogical approaches to classroom discourse that produce desirable outcomes for diverse students? It draws on data from the Effective Pedagogy in Mathematics/Pāngarau: Best Evidence Synthesis Iteration [BES] (Anthony & Walshaw, 2007). Confining our search to studies undertaken in English-speaking countries, the search took into account relevant publications within the mathematics education literature, first and foremost, and was complemented by general and specialist education literature.

In our first pass through the literature, we noted that many studies offered detailed explanations of student outcomes yet failed to draw conclusive evidence about how those outcomes related to specific teaching practices. Others provided detailed explanations of pedagogical practice yet made unsubstantiated claims about, or provided only inferential evidence for, how those practices connected with student outcomes. These particular studies did not satisfy our selection criteria, precisely because we were searching for studies that offered not just descriptions of pedagogy and outcomes but rigorous explanation for close associations between pedagogical practice and student academic and social outcomes.

Decisions over outcomes were guided by the National Research Council's (2001) understanding of mathematical proficiency. We included conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. We added to these specific academic outcomes a range of other outcomes that relate to affect, behaviour, communication, and participation.

Included are many different kinds of evidence that take into account human volition, programme variability, cultural diversity, and multiple perspectives. Each study, characterised by its own way of looking at the world, has led to different kinds of truth claims and different ways of investigating the truth. Our assessments about the quality of research depended on the nature of the knowledge claims made and the degree of explanatory coherence between those claims and the evidence provided.

In reviewing the work undertaken in this area, we found that a number of critical aspects of pedagogical practice came to the fore. These included: (a) articulating thinking,

(b) fine-tuning mathematical thinking through language, (c) communicating within multilingual contexts, and d) shaping mathematical argumentation. We use these themes to organise the literature on classroom discourse. Each theme serves as a point of discussion, providing insight into definitions of effective domain-specific pedagogy relating to classroom discourse in mathematics classrooms.

Results

Articulating Thinking

There is now a large body of empirical and theoretical evidence that demonstrates the beneficial effects of participating in mathematical dialogue within the classroom (e.g., Clarke, Keitel, & Shimizu, 2006; Fraivillig, Murphy, & Fuson, 1999; Goos, 2004; Kazemi & Franke, 2004; McClain & Cobb, 2001; Mercer, 2000; O'Connor, 2001; Sfard & Kieran, 2001; White, 2003; Wood, Williams, & McNeal, 2006). However, many of the same researchers who elevate student articulation of mathematics thinking have, simultaneously, cautioned that providing comprehensible explanations about mathematical concepts is essentially a learned strategy. Sfard and Kieran (2001) emphasise that "the art of communicating has to be taught" (p. 70). It is a major challenge to make discourse integral to an overall strategy of teaching and learning.

A number of studies have found that, without pedagogical support, students are often not able to elaborate on their mathematical reasoning. Effective pedagogy focused on support, demands careful attention to students' articulation of ideas. Franke and Kazemi (2001) make the important claim that an effective teacher tries to delve into the minds of students by noticing and listening carefully to what students have to say. Yackel, Cobb, and Wood (1990) provide evidence to substantiate the claim. They report on the ways in which one Year 2 teacher listened to, reflected upon, and learned from her students' mathematical reasoning while they were involved in a discussion on relationships between numbers. Analyses of the discussion revealed that her mathematical subject knowledge and her focus on listening, observing, and questioning for understanding and clarification greatly enhanced her understanding of students' thinking.

Other researchers (e.g., Davies & Walker, 2005; Jaworski, 2004) have also drawn attention to the critical role of the teacher in listening to students and orchestrating mathematical discourse. In a study undertaken within a heterogeneously grouped seventh-grade mathematics classroom, Manouchehri and Enderson (1999) found that the teacher provided responsive rather than directive support, all the while monitoring student engagement and understanding. She did this through careful questioning, purposeful interventions, and with a view towards shifting students' reliance from her, towards the support and the challenge of peers. The teacher's primary objectives were to facilitate the establishment of situations in which students had to share ideas and elaborate on their thinking, to help students expand the boundary of their exploration, and to invite multiple representations of ideas.

Fraivillig, Murphy, and Fuson (1999) reported on the discursive exchange of ideas that took place within a Year 1/2 classroom. What was particularly effective was the way the teacher sustained the discussions. She developed a sensitivity about when to "step in and out" of the classroom interactions and had learned how to resolve competing student claims and address misunderstanding or confusion (theirs and hers). For their part, the students listened to others' ideas and participated in debates to establish common meanings.

Knowing when to "step in" is important for teachers focused on making a difference to students' learning. Turner and colleagues (2002) found that what distinguished high-involvement Year 5 and 6 classrooms was the engagement of the teachers in forms of instruction that allowed them to "step in" at significant moments during classroom discussions. In particular, the teachers negotiated meaning through "telling" tailored to students' current understandings. They shared and then transferred responsibility so that students could attain greater autonomy. In these classrooms, telling was followed by a pedagogical action that had the express intent of finding out students' understandings and interpretations of the given information.

Hill, Rowan, and Ball (2005) have found from observations in their Study of Instructional Improvement that effective practice requires a moment-by-moment synthesis of actions, thinking, theories, and principles. In their Leverhulme Numeracy Research Program, Askew and Millett (in press) observed that pedagogical practice that makes a difference for all learners requires professional reflecting-in-action. In particular, teachers who were able to develop student mathematical understanding applied sound subject knowledge to inform their on-the-spot decision making during classroom interactions. Subject knowledge informed decisions about the particular content that the students would learn, the activities they carried out, how they engaged with the content, and how they conveyed to the teacher their understanding of the content.

Fine-tuning Mathematical Thinking Through Language

Engagement in effective classroom discourse is "a complex process that combines doing, talking, thinking, feeling, and belonging" (Wenger, 1998, p. 56). As we have seen, engagement in discourse that successfully advances students' understanding, demands a respectful exchange of ideas, teacher listening, attentiveness, and reflection-in-action. It also involves familiarising students into mathematical convention. Effective teachers are able to bridge students' intuitive understandings with the mathematical understandings sanctioned by the world at large. Language plays a central role in building these bridges: it constructs meaning for students as they move towards modes of thinking and reasoning characterised by precision, brevity, and logical coherence (Marton & Tsui, 2004). In particular, the teacher who makes a difference for diverse learners is focused on shaping the development of novice mathematicians who speak the precise and generalisable language of mathematics.

McChesney (2005) explored students' contributions in low- and middle-band New Zealand classes at the junior secondary school level. She noted that teachers who established classroom communities, in which there was access to discursive resources, were able to support students' mathematical activity significantly. Her research demonstrated a direct relationship between the quality of teacher/student interaction and students' negotiation of mathematical meaning. The effective teachers in this research were able to set up an environment in which conventional mathematical language migrated from the teacher to the students. Over time, students' contributions, which were initially marked by informal understandings, began to appropriate the language and the understandings of the wider mathematical community. It was through the take-up of conventional language that mathematical ideas were seeded.

Khisty and Chval (2002), among others, have reported that the language that students use derives from the language used by their teacher. Hence the meanings that students construct ultimately descends from those captured through the kind of language the teacher uses. In order to enculturate students into the mathematics community, effective teachers share with their students the conventions and meanings associated with mathematical discourse, representation, and forms of argument.

Competency in mathematics demonstrates control over the specialised discourse (Gee & Clinton, 2000). But the specialised language of mathematics can be problematic for learners. Particular words, grammar, and vocabulary used in school mathematics can hinder access to the meaning sought and the objective for a given lesson. Words, phrases, and terms can take on completely different meanings from those that they have in the everyday context. Sullivan, Mousley, and Zevenbergen (2003) found that students with a familiarity of standard English (usually students from middle-class homes) had greater access to school mathematics. As the teachers in their study said, the students were able to “crack the code” of the language being spoken.

Lubienski (2002), as teacher-researcher, compared the learning experiences of students of diverse socio-economic status (SES) in a seventh-grade classroom. She reported that higher SES students believed that the patterns of interaction and discourse established within the classroom helped them learn other ways of thinking about ideas. The discussions helped them reflect, clarify, and modify their own thinking, and construct convincing arguments. However, in Lubienski’s study, the lower SES students were reluctant to contribute because they lacked confidence in their ability. They claimed that the wide range of ideas contributed in the discussions confused their efforts to produce correct answers. Their difficulty in distinguishing between mathematically appropriate solutions and nonsensical solutions influenced their decisions to give up trying. Pedagogy, in Lubienski’s analysis, tended to privilege the ways of being and doing of high SES students.

Communicating Within Multilingual Contexts

Mathematical language presents difficulties to students, in general, and presents certain tensions in multilingual classrooms, in particular. In our reading of the literature we found a number of studies that had investigated the specific challenges of teaching mathematics in multilingual contexts (Adler, 2001; Khisty, 1995; Moschkovich, 1999). Neville-Barton and Barton (2005) looked at these tensions as experienced by Chinese Mandarin-speaking students in New Zealand schools. Their investigation focused on the difficulties that could be attributable to limited proficiency with the English language. It also sought to identify language features that might create difficulties for students. Two tests were administered, seven weeks apart. In each, one half of the students sat the English version and the other half sat the Mandarin version, ensuring that each student experienced both versions. There was a noticeable difference in their performances on the two versions. On average, the students were disadvantaged in the English test by 15%. What created problems for them was the syntax of mathematical discourse. In particular, prepositions, word order, and interpretation of difficulties arising out of the contexts. Vocabulary did not appear to disadvantage the students to the same extent. Importantly, Neville-Barton and Barton found that the teachers in their study had not been aware of some of the student misunderstandings.

Similar difficulties were made evident in students from Sāmoa and Tonga, in Latu’s (2005) research. Latu noted that English words are sometimes phonetically translated into

Pasifika languages to express mathematical ideas when no suitable vocabulary is available in the home language. The same point was made by Fasi (1999) in his study with Tongan students. Concepts such as "absolute value", "standard deviation", and "simultaneous equations" and comparative terms like "very likely", "probable", and "almost certain" have no equivalent in Tongan culture, whereas some English words, such as "sikuea" (square), have multiple Tongan equivalents.

Fasi (1999) investigated the discursive approaches of two teachers, one Sāmoan and the other Tongan, both of whom had been educated in their native country before moving to New Zealand to complete their higher education. He found that the teachers switched between the language of instruction and the learners' main language in order to explain and clarify the concepts to students. Clarkson (1992) and Setati and Adler (2001) all found evidence of language switching (code switching) for bilingual students, particularly when students could not understand the mathematical concept or when the task level increased. Code switching involved words and phrases as well as sentences and tended to enhance student understanding.

Shaping Mathematical Argumentation

We have now looked at the approaches teachers take to fine tune thinking through language. But mathematical language involves more than technical vocabulary. It also encompasses the way it is used within mathematical argumentation. The positive effects of providing regular opportunities for students to engage in argumentation have been well documented (Carpenter & Lehrer, 1999; Cobb, Boufi, McClain, & Whitenack, 1997; Empson, 2003; Goos, 2004; Kazemi & Stipek, 2001; McClain & Cobb, 2001; O'Connor, 2001; Wood & McNeal, 2003; Zack & Graves, 2002). These researchers have provided evidence that students should have the opportunity and space, for example, to interpret, generalise, justify, and prove their ideas, as well as critique the ideas of others in the class.

Many researchers have found that pedagogical practices that allow students to engage in these activities greatly enhance the development of their mathematical thinking. Such practices also enhance the view that students hold of themselves as mathematics learners and doers. In particular, O'Connor and Michaels (1996) have highlighted the importance of shaping mathematical argumentation by fostering students' involvement in taking and defending a particular position against the claims of other students. They point out that this instructional process depends upon the skilful orchestration of classroom discussion by the teacher. The skill "provides a site for aligning students with each other and with the content of the academic work while simultaneously socialising them into particular ways of speaking and thinking" (p. 65).

As straightforward as it might seem, shaping students' mathematical thinking is, in fact, a highly complex activity. It is complex because teachers and students are "negotiating more than conceptual differences … they are building an understanding of what it means to think and speak mathematically" (Meyer & Turner, 2002, p. 19). Watson (2002) reported that teaching mathematics to low-attaining students in secondary school often involved "simplification of the mathematics until it becomes a sequence of small smooth steps which can be easily traversed" (p. 462). Frequently teachers took the student through the chain of reasoning and students merely filled in the gaps with the arithmetical answer, or low-level recall of facts. This "path smoothing", it was found, did not lead to sustained learning precisely because the strategy deliberately reduced a problem to what the learner could already do, with minimal opportunity for cognitive processing.

Fraivillig and colleagues (1999) observed teachers who did not simplify the task demands. Teachers in their research did more than sustain discussion – they moved conversations in mathematically enriching ways, they clarified mathematical conventions, and they arbitrated between competing conjectures. In short, they picked up on the critical moments in discursive interactions and took learning forward. Hiebert and colleagues (1997) have found that relevant and meaningful teacher responses to student talk involves drawing out the specific mathematical ideas set within students' methods, sharing other methods, and advancing students' understanding of appropriate mathematical conventions. Reframing student talk in mathematically acceptable language provides teachers with the opportunity to enhance connections between language and conceptual understanding.

Zack and Graves (2002) have reported that teachers who develop student argumentation and enhance learning are themselves active searchers and enquirers into mathematics. O'Connor's (2001) classroom research highlighted how one teacher, through purposeful listening, facilitated a group of students towards a mathematical solution. The research students took varying positions towards the solution and attempted to support those positions with evidence. The teacher made her contribution by challenging the students' claims through the use of counter-examples.

Goos (2004) described how a secondary school mathematics teacher developed his students' mathematical thinking through scaffolding the processes of inquiry. The teacher "call[ed] on students to clarify, elaborate, critique, and justify their assertions. The teacher structured students' thinking by leading them through strategic steps or linking ideas to previously or concurrently developed knowledge" (p. 269). In a series of lesson episodes, Goos provided evidence of how the teacher pulled learners "forward into mature participation in communities of mathematical practice" (p. 283), until they were able to engage independently with mathematical ideas.

On other studies Stein, Grover, and Henningsen (1996) and Kazemi and Franke, (2004) have found that a sustained press for justifications, explanations, and meaning, significantly contributed to high-level cognitive activity. When a teacher "presses a student to elaborate on an idea, attempts to encourage students to make their reasoning explicit, or follows up on a student's answer or question with encouragement to think more deeply" (Morrone, Harkness, D'Ambrosio, & Caulfield, 2004, p. 29), the teacher is not only providing an incentive for students to enrich their knowledge, but also socialising them into a larger mathematical world that honours standards of reasoning and rules of practice. In effect, by participating in a "microcosm of mathematical practice" (Schoenfeld, 1992), students are learning how to appropriate mathematical ideas, language, and methods and how to become apprentice mathematicians.

Conclusion

This review represents a systematic and credible evidence base about quality discourse in mathematics classrooms and explains the sort of pedagogical approaches that lead to improved engagement and desirable outcomes for learners from diverse social groups. Our search through the literature focused attention on different contexts, different communities, and to multiple ways of thinking and working. The evidence drew on the histories, cultures, language, and practices found in mathematics classroom contexts and considered a range of research evidence irrespective of regardless of methodological approaches.

Our focus on classroom discourse and scaffolding of student engagement has revealed specific pedagogical skills, knowledges and dispositions that make a difference to all students. These pedagogical factors shape how, and with what effect, mathematics is taught and learned. Student outcomes are contingent upon them, not as single entities, but as interrelated contingencies. Although our review has surveyed the literature on mathematics classroom discourse, it is important to note that classroom discourse will gain positive effect only when there is a strong cohesion between all the various elements of a teacher's work. In other words, the facilitation of productive classroom discourse is part of a larger matrix of the effective teacher's repertoire that allow students to develop habits of mind to engage with mathematics productively and to make use of appropriate mathematical tools to support understanding.

Our review has deepened our understanding of mathematics discursive practices in many ways. Teachers who set up communities of practice that are conducive to classroom discussion, come to understand their students better. Students benefit too and the ideas put forward in the classroom become rich resources for knowledge. Through students' purposeful involvement in discourse, through listening respectfully to other students' ideas, through arguing and defending their own position, and through receiving and providing a critique of ideas, students enhance their own knowledge and develop their mathematical identities. Teachers who are able to provide such contexts simultaneously increase students' sense of control, and develop valuable student mathematical dispositions.

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