Talking in and about mathematics classrooms: Student and teacher learning

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There is no higher priority in the field of education than the study of the nature and promotion of learning. As a focus of research, learning and its promotion require investigation at levels that extend from the neurological to the socio-cultural, in a variety of settings both institutionalised and personal, and with respect to all conceivable attributes, inclinations and skills, from aspects of recall through specific knowledge domains to strategies for self-regulation.

Classrooms represent a globally-extensive institutionalised site for the promotion of learning. Mathematics is a content domain universally represented in all national curricula. As a consequence, mathematics classrooms represent a research site of international relevance for investigating the social nature of learning.

However, the function of social interaction in learning is a major research challenge yet to be adequately addressed. In the following discussion, we argue that a timely convergence of contemporary theory and available research methods and resources provides researchers with much-needed tools to investigate the social nature of learning and the role of social interaction in promoting learning in classroom settings.

We illustrate our points with key findings from four complementary projects:

- a comparative study of classroom discourse undertaken in 22 mathematics classrooms across eight countries (The Learner's Perspective Study)
- the study of student learning when engaged in individual, pair and collaborative group work (The Social Unit of Learning Project),
- the role of teacher selective attention in facilitating teacher professional learning (The Learning from Lessons Project) and
- the identification of the professional lexicon employed by middle school mathematics teachers in Australia and eight other countries to describe the events of the mathematics classroom (The Lexicon Project).

These four studies find their nexus in the social nature of learning in classrooms. We discuss the implications of the project findings for the optimal functioning of the mathematics classroom as a site for student and teacher learning.

Comparing classroom talk in eight countries

Comparison of mathematics classrooms in Shanghai, Seoul, Tokyo, Hong Kong, Singapore, Berlin, San Diego and Melbourne revealed profound differences in who spoke in the classroom (teacher or student), what they said (technical language) and the conditions under which they spoke (public and private speech by individuals, but also whole class choral response). These differences call into question the advocacy of student to student mathematical talk that is so strongly promoted in the educational literature in countries such as Australia and the USA. It should be noted that in classrooms such as those in Shanghai, students are frequently given opportunities to engage in mathematical talk, but exclusively through public speech, either individually or as part of a whole-class choral response. Post-lesson interviews with students suggest that the Shanghai students developed a level of fluency in the technical language of mathematics comparable to their counterparts in the Melbourne classrooms (Kaur, Anthony, Ohtani, & Clarke, 2013).

From consideration of the Korean classrooms, in particular, it appears that high scores can be achieved on international tests of student mathematics performance (such as the Programme for International Student Assessment [PISA] and the Third International Mathematics and Science Study [TIMSS]) through classroom practices in which students seldom speak in public and never in private. Yet students in all countries studied, when asked to identify significant moments in a mathematics lesson, consistently pointed to opportunities to articulate their thinking or to listen to the explanations of their classmates—except in the Korean classrooms, where it never happened. What is it that these students (and Western researchers and educational theorists) are seeing as so important?

The data generated in this study provided many examples of sophisticated and highly motivated student–student mathematical talk; whether in the Melbourne classroom, the San Diego classroom or the mathematics classroom in Tokyo. Yet the purported benefits of these rich mathematical conversations are not revealed in large-scale international testing. This leaves us with the question of what learning benefits accrue from student classroom talk.

Collaborative problem solving in a laboratory classroom

At the University of Melbourne, it is now possible to study student collaborative work in a classroom equipped with up to 16 video cameras and 32 audio inputs. This “laboratory classroom” makes it possible to document the speech and actions of each individual in a class of 24 students, including the teacher. In the Social Unit of Learning Project, students undertake mathematical tasks individually, in pairs, in groups of four and as a whole class. Through partnership arrangements with a Victorian government secondary school, students undertake the tasks as members of their usual mathematics class, taught by their usual teacher. In this way, the students’ well-established routines of interaction with their classmates and with their teacher are retained. Technical facilities in the classroom generate a complete video record of each student together with digital records of any written work produced, and every word spoken is transcribed.

This sophisticated facility, unmatched elsewhere in the world, allows the simultaneous recording of student–student and student–teacher interactions, while the students all attempt the same mathematical tasks, whether as individuals, pairs or small groups. This makes possible the investigation of those group interactive characteristics that can be associated with sophisticated mathematical performance and/or particularly effective or sophisticated negotiative interactions, whether between students or between the teacher and a particular group of students.

Recent analysis makes it clear that students have far more than just the mathematics to negotiate. Significant time and effort go into negotiating the socio-mathematical norms of the classroom (e.g., the shared understanding between teacher and students of what constitutes an adequate solution) and the social arrangements essential to effective group functioning (e.g., who does what). In such collaborative situations, students are learning not just mathematical facts and procedures, but forms of mathematical argumentation and problem solving, and ways to optimise the team’s collaborative activity. In the Social Unit of Learning Project, we manipulate both the type of tasks and the social unit by which the tasks are undertaken (individual, pair, small group) in order to investigate the nature of group problem solving and learning and to identify those behaviours that appear to be associated with the improved student functioning in all three domains: mathematical, socio-mathematical and social. Ultimately, we hope to inform teachers regarding forms of intervention to optimise student development in all three domains.

Learning from lessons: Focusing on teacher learning

In recent years, a great deal of research has been conducted that provides evidence for what many intuitively believe to be true—that ultimately the teacher is the key to improved student learning (Hattie, 2003). Despite the growing recognition of the centrality of the teacher’s role to student learning, teacher knowledge and teacher learning remain under-theorised. This project draws on Shulman’s (1987) conception of the “wisdom of practice”, in which teacher expertise is seen as developing through instructional and other professional activity and takes as its starting point

one of the most widely cited models of teacher learning (Clarke & Hollingsworth, 2002). Central to this model is the mediating role played by Salient Outcomes (those outcomes of classroom practice to which the teacher attaches significance), which provide both the basis for change in beliefs and knowledge and, once changed, the motivation to engage in classroom experimentation in recognition of changes in those outcomes considered salient by the teachers.

The project is structured around three research questions:

- What do teachers learn from the activities associated with teaching a lesson? (Such activities include preparing, teaching and reflecting on the lesson)
- What conditions appear to affect the process and products of this learning?
- (In particular, what is the role played by teacher selective attention?)
- How might this learning process be facilitated? (Through the teacher's own actions, through the provision of support material, through collegial support structures)

A key element in this research design is the provision of purposefully-designed experimental mathematics lessons, which provide the initial context for this study of teacher selective attention, reflection and learning. The teacher is encouraged to adapt the provided lesson to the needs of their class, teach the lesson, and then construct and teach the next lesson, building on the outcomes of the first. Interviews are conducted before and after each lesson and video is used to stimulate the teacher's recollection of significant moments in the lesson. Teacher beliefs, mathematical knowledge, and pedagogical content knowledge are also assessed.

Preliminary analyses support a model of teacher in situ learning that includes:

1. what the teacher already knows and believes
2. those classroom objects and events to which the teacher attends
3. the meaning associated by the teacher with those objects and events
4. the in-the-moment decisions made by the teacher while teaching a lesson
5. the teacher's inclination and capacity to reflect productively on their practice.

Analysis undertaken in this project has identified teacher learning with respect to mathematics, instruction and the student (Clarke, Clarke, Roche & Chan, 2015). This learning can be connected to those things to which the teacher attends. And these objects of teacher attention are dependent on the professional vocabulary of the teacher, by which they can name and discuss the objects and events of the classroom.

In relation to the goal of optimising teacher learning in classrooms, it appears that the provision of mathematically and instructionally "rich" lessons can catalyse teacher learning about their students' mathematical thinking. Particular activities appear to optimise this learning:

- rehearsing the lesson's activities beforehand
- facilitated structured reflection on the lesson
- design of a subsequent lesson using a structured lesson template
- guided teacher attention during the lesson.

Currently, the principal vehicle for institutionalised in-service teacher learning seems to be the formally delivered professional development session or program. The optimisation of teacher "on the job" learning through the activities associated with teaching a lesson offers a potentially more efficient and effective strategy for promoting teacher learning as an integral component of their daily professional activity. One key to this optimisation is to equip teachers with a more sophisticated and extensive professional lexicon.

The Lexicon Project

Classroom researchers, teacher educators and teachers all find themselves obliged to describe and discuss the phenomena of the classroom. The international Lexicon Project seeks to document the professional lexicon employed by middle school mathematics teachers in Australia, Chile, China, the Czech Republic, Finland, France, Germany, Japan and the USA. In each country, the documentation of the local lexicon is proving to be a productive end in itself, compelling each community to review their assumptions about locally shared terms and meanings. Internationally, the comparison of the separate lexicons is revealing remarkable silences in some

languages and unusual terms in others, foregrounding particular features of the classroom in one culture, while these same features are left unnamed by another community.

The internationalisation of education should offer new possibilities for practice by providing access to new ideas and approaches. However, the establishment of English as the international language of education has the unfortunate side effect of restricting international access to the sophisticated constructs used in non-English speaking countries to describe and evaluate classroom practice.
The Sapir-Whorf hypothesis has been with us for some time and it succinctly summarises one of the underlying principles of this project.

We see and hear . . . very largely as we do because the language habits of our community predispose certain choices of interpretation (Sapir, 1949).

If an activity is named, it can be recognised and it becomes possible to ask: 'how well is it done?' and 'how might it be done better?' An unnamed activity is less accessible for research analysis. In such a situation, practising teachers are denied recognition of an activity that at least one culture values enough to name. Further, an unnamed activity will be absent from any catalogue of desirable teacher actions and consequently denied specific promotion in any program of mathematics teacher education. Actions considered as essential components of the mathematics teacher's repertoire in one country: for example, mise en commun (France), pudian (China) or matome (Japan), may be entirely absent from any catalogue of accomplished teaching practices in English.

Mise en commun: A whole class activity in which the teacher elicits student solutions for the purpose of drawing on the contrasting approaches to synthesise and highlight targeted key concepts.

Pudian: An introductory activity in which the teacher elicits student prior knowledge and experience for the purpose of constructing connections to the content to be covered in the lesson.

Matome: A teacher-orchestrated discussion drawing together the major conceptual threads of a lesson or extended activity—most commonly a summative activity at the end of the lesson.

The international dominance of English has denied researchers, teacher educators and practitioners access to many sophisticated classroom-related terms in languages other than English, which might otherwise contribute significantly to our understanding of classroom instruction and learning. The initial product of the Lexicon Project is a 'National Lexicon' for each participating community, with English definitions and descriptive detail, supported by video exemplars. At the time of writing, the research team in each participating country has produced a draft lexicon and each is currently undertaking a process of national validation.

Once documented and validated, each National Lexicon can be analysed to identify its characteristic features; for example, the relative proportions of terms referring to teacher activities or student activities; the proportion of terms that are specific to mathematics classrooms and those that might apply to any classroom. Specific types of terms will be of particular interest: e.g., terms in one language naming a familiar but unnamed practice in another language; or terms naming an activity wholly absent from the classrooms of one community. The Lexicon Project has the potential to enrich the professional vocabulary of speakers of many languages, but, particularly, to enrich the international community's capacity to utilise the insights into sophisticated classroom practice encrypted in non-English languages.

The overarching goal

Many of the processes by which educational phenomena are experienced and by which the products of the learning process are enacted are essentially social. Innovative research designs are needed to distinguish the social aspects of the learning process and, particularly, those for which 'the social' represents the most fundamental and useful level of explanation and modelling.

Learning at the social level has proved particularly difficult to research and consequently to model and explain. All four projects reported here take the social situation of the classroom as their point of reference and investigate the practices that we find there. The overarching goal of all four projects is to optimise both student and teacher learning through research that recognises the social nature of such learning and, by understanding how this learning occurs, better assist its promotion for both students and teachers.

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