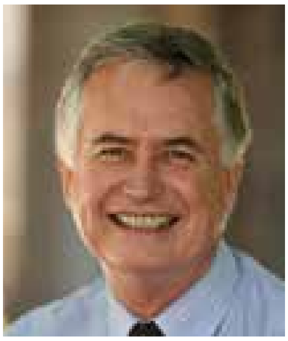
CHALLENGES AND OPPORTUNITIES FOR NEUROSCIENCE:
HOW TO EXPLAIN THE CONNECTION BETWEEN SOCIOCULTURAL PRACTICES AND COGNITION?



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Professor David Clarke is the Director of the International Centre for Classroom Research (ICCR) at the University of Melbourne. Over the last 20 years, his research activity has centred on capturing the complexity of classroom practice through a program of international video-based classroom research. The ICCR provides the focus for collaborative activities among researchers from more than 20 countries. Professor Clarke has worked with school systems and teachers throughout Australia and in the USA, Canada, Sweden, Germany, the Netherlands, Italy, Singapore, China, Japan, Malaysia and the Federated States of Micronesia. Other significant research by Professor Clarke has dealt with teacher professional learning, metacognition, problem-based learning, and assessment (particularly the use of open-ended tasks for assessment and instruction in mathematics). Current research activities involve multi-theoretic research designs, cross-cultural analyses, discourse in and about classrooms internationally, curricular alignment and the challenge of research synthesis in education. Professor Clarke has written books on assessment and on classroom research and has published his research work in more than 150 book chapters, journal articles and conference proceedings papers.

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Dr Hilary Hollingsworth's main areas of interest are teacher professional learning and the assessment of student learning, and her current work foci include teacher evaluation and assessment, classroom observation frameworks, the use of video for teacher professional learning and the assessment of student learning. Dr Hollingsworth's interest in these areas was sparked by her doctoral studies and her extensive international experience working as the Australian representative on the TIMSS Video Study projects and as a director of teacher learning for LessonLab in Los Angeles, California. Dr Hollingsworth's experience related to teacher professional learning and the assessment of student learning extends across system and school levels. She has developed graduate programs and professional learning modules for teachers, and delivered numerous keynote addresses at education conferences. She regularly provides consultancy services to schools in different sectors and geographical regions, and completes projects for organisations including the Australian Association of Mathematics Teachers, the Australian Institute for Teaching and School Leadership, and Education Services Australia. Dr Hollingsworth has recently worked as a senior lecturer in the Melbourne Graduate School of Education at the University of Melbourne and is conducting research there related to classroom observations and feedback to teachers.

ABSTRACT

Large-scale international comparative studies of teaching and learning such as the TIMSS 1999 Video Study (Hiebert et al., 2003) and the Learner's Perspective Study (Clarke, Keitel & Shimizu, 2006) offer many instances of profound differences in teacher and student behaviours in different classrooms around the world. In particular, the classroom practices of high-achieving communities frequently seem to contradict the prescriptions of empirical research conducted in Western settings. It has been argued that pedagogies in different cultures appear to be predicated on different assumptions about both the process and the product of learning in classroom settings (Clarke, 2013). These include differences in the role accorded to such things as spoken language, physical activity, and student self-regulation in the learning process. Examples from the LPS and TIMSS video projects will be used to illustrate these differences. Such findings have been interpreted as differences in sociocultural performance rather than in cognition itself, leaving unexplored the possibility that people in different cultures might learn in fundamentally different ways. Can neuroscience help us understand the variation that we find in cross-cultural classroom studies? Cross-cultural studies of teaching and learning provide both a challenge and an opportunity to determine what is truly fundamental to human learning.

INTRODUCTION

Large-scale international comparative studies of teaching and learning such as the TIMSS 1999 Video Study (Hiebert et al., 2003; Hollingsworth, Lokan & McCrae, 2003) and the Learner's Perspective Study (Clarke, Keitel & Shimizu, 2006) offer many instances of profound differences in teacher and student behaviours in different classrooms around the world. In particular, the classroom practices of high-achieving communities frequently seem to contradict the prescriptions of empirical research conducted in Western settings. It has been argued that pedagogies in different cultures appear to be predicated on different assumptions about both the process and the product of learning in classroom settings (Clarke, 2013). These include differences in the role accorded to such things as spoken language, physical activity and student self-regulation in the learning process. Such findings have been interpreted as differences of sociocultural performance rather than in cognition itself, leaving unexplored the possibility that people in different cultures might learn in fundamentally different ways.

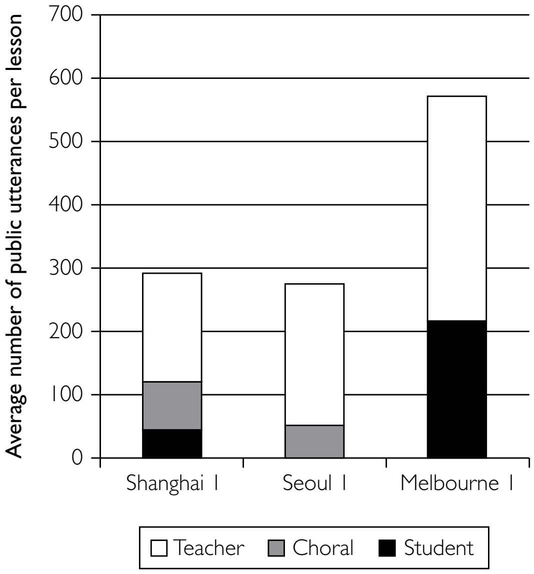
There are also specific findings related to learning preferences and patterns of instructional practice that show remarkable consistency across cultural settings (Givvin, Hiebert, Jacobs, Hollingsworth & Gallimore, 2005). These consistencies across classrooms, whose practice reflects such different pedagogical traditions, suggest that some aspects of human learning transcend cultural context and suggest the possibility of biological or neurological rather than sociocultural explanations.

It is a key premise of this presentation that explanation of learning is possible from both sociocultural and neurological perspectives. These explanations will take different forms and appeal to different theories. In some cases, hypothesised relationships identified in one domain may assist us to understand phenomena identified as significant in the other domain. For example, the function of attention in learning may be understood neurologically, while individual inclinations to attend to some forms of stimuli rather than to others may be most usefully understood in sociocultural terms. Equally, as will be discussed, the significance attached by students across cultures to the explanations of their peers may be usefully explained in neurological terms, drawing on research into the role of empathy in facilitating learning. Importantly, the recommendations arising from such different explanatory accounts may lead to different forms of instructional advocacy.

In this discussion, we offer some of the patterns and hypotheses suggested by sociocultural analyses and pose questions about the contribution that neuroscience might make to our understanding of learning in social settings such as classrooms and the consequences for instructional advocacy of the connections we might make between explanations provided by these two research communities. Examples from the Learner's Perspective Study and TIMSS video projects will be used to illustrate the patterns and hypotheses arising from sociocultural analyses and to pose some of the questions that might be amenable to neurological investigation. Additional examples will be drawn from other fine-grained video studies. These sociocultural studies of teaching and learning provide both a challenge and an opportunity to determine what forms of explanation might best inform the promotion of learning in classroom settings.

LANGUAGE AND LEARNING

Recent cross-cultural studies of teaching and learning have problematised the exclusive advocacy of particular instructional principles. For example, a consistent message of research conducted in Australian, European and US classrooms has been the advocacy of student classroom talk as essential to effective student learning. 'Students' participation in conversations about their mathematical activity (including reasoning, interpreting, and meaning-making) is essential for their developing rich, connected mathematical understandings' (Silverman & Thompson, 2008, p. 507). Despite the emphatic advocacy in Western educational literature, classrooms in China and Korea have historically not made use of student–student spoken mathematics as a pedagogical tool (see Figures 1 and 2).



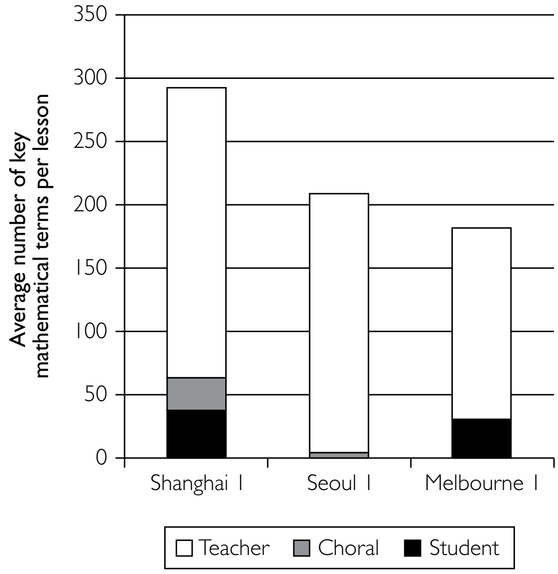


Figure 1 A comparison of public speech in three mathematics classrooms: utterances and mathematical terms, respectively (each bar represents the average of five lessons)

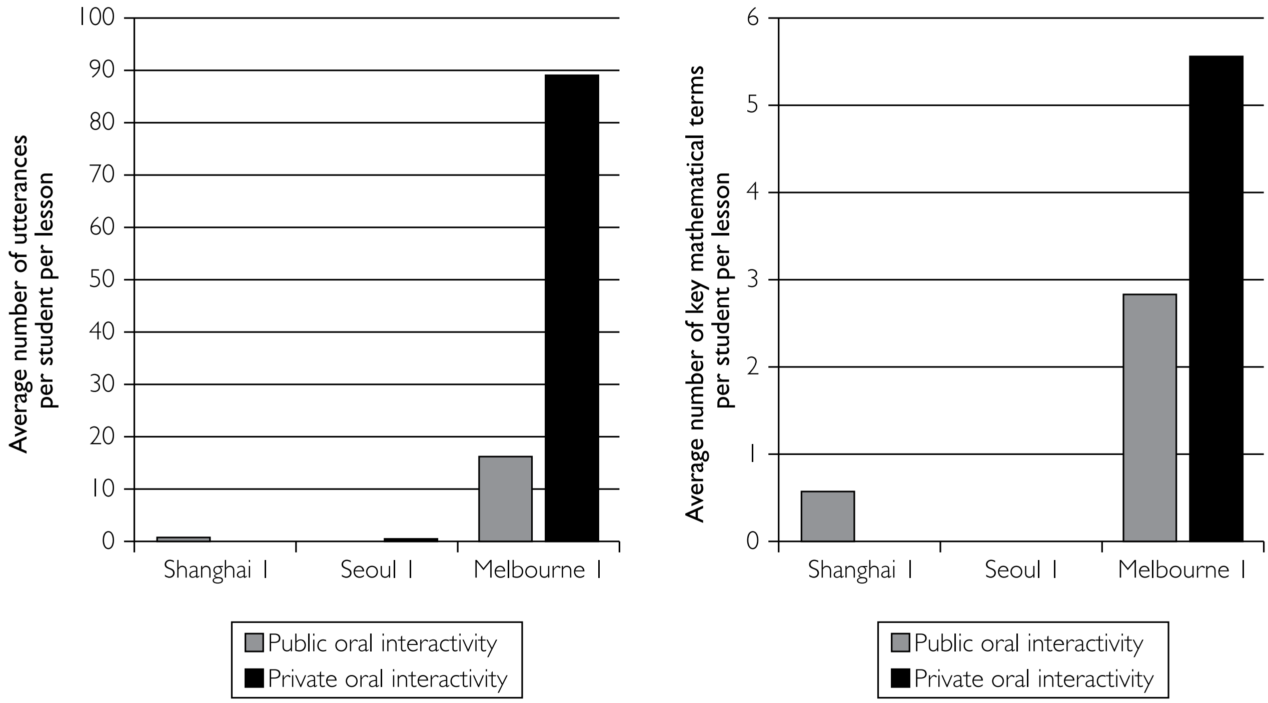


Figure 2 Comparison of public and private speech for three mathematics classrooms

As models of classroom pedagogy, these three classrooms offer quite distinct alternatives. If we focus only on public speech (Figure 1), we can see clear differences with respect to the relative proportion of teacher and student public speech and in the use of whole class (choral) response. Another significant difference is the relative prioritisation of student use of technical mathematical terms in public speech.

In research undertaken by Clarke, Xu and Wan (2010), classrooms were identified in which student fluency in the spoken use of technical mathematical terms (student spoken mathematics) was purposefully promoted in public interactions but not in private ones (for example, Shanghai classroom 1), in both public and private interactions (for example, Melbourne 1), and in neither public nor private interactions (for example, Seoul 1). Each of these classrooms enacts a distinctive pedagogy with respect to student-spoken mathematics. All three classrooms were successful in promoting student competence in completing written mathematical tasks. The students in the Shanghai and Melbourne classrooms were similar in their fluent use of technical mathematical terms in post-lesson interviews (Clarke, 2010), a capability not demonstrated by the students from the Seoul classroom.

The Korean graduates from classrooms similar to the Seoul classroom have been consistently successful in large-scale international achievement studies (TIMSS and PISA). This success appears to be achieved in classrooms that place almost no emphasis on students' spoken participation.

Despite the strident advocacy of some researchers, it appears that some forms of mathematical learning do not require student speech as an essential mediator of that learning. On the other hand, if facility with the language of mathematics is a valued outcome, it is not surprising that proficiency requires the provision of opportunities to rehearse such language use. An opportunity exists for neuroscience to help us distinguish between the types of learning that can be promoted successfully without the mediation of student speech and those types of learning that are facilitated by student speech.

REASONING, METACOGNITION AND PROBLEM SOLVING

A further question remains regarding the promotion of student mathematical reasoning, as distinct from either the ability to replicate taught procedures or to employ mathematical terminology appropriately. This is particularly of interest in situations where the problem requiring solution is unfamiliar to the individual attempting solution. In relation to such performances, it may be neither calculational proficiency nor facility with mathematical terminology that equips the problem solver for success. Instead, participation in socially enacted argumentation, where this argumentation is framed through meta-rules of discursive classroom practice (Xu & Clarke, 2013), may serve to model forms of metacognitive regulation as social rules, which the student internalises as metacognitive routines (Holton & Clarke, 2006).

In the TIMSS 1999 Video Study public release video of Japan Lesson 3, work on the first problem extended across the first 44 minutes of the lesson. The basic instructional sequence was this: teacher introduced the problem; teacher observed and assisted while students worked on the problem; teacher invited selected students to present their solutions; and teacher summarised solution methods. This teaching and learning sequence would seem familiar and unsurprising. But close analysis of the lesson video revealed a carefully crafted sequence of deliberate teaching acts that provided sophisticated scaffolding for problem solving. For example:

- the teacher devoted significant time – 4 minutes 25 seconds – to ensuring that students understood precisely what the problem was asking
- the teacher used carefully prepared diagrammatic and textual 'props' to demonstrate key aspects of the problem statement
- as students worked on the problem, the teacher interacted with individuals, posing questions that provided direction or provoked further thought
- as the teacher observed students at work, he noted the methods that they used to solve the problem and carefully selected students to present their solution methods. The teacher ensured that a range of methods was included and that each method was strategically positioned on the board to create a record of method types in order of sophistication. The students were asked to both write and explain their solution methods.
- as the teacher summarised the problem, he made explicit links between the different methods presented by the students and a particular method for illustrating inequalities that he introduced next.

In this example, we see Japanese pedagogy in microcosm: sophisticated teaching practice using a number of deliberate and strategic pedagogical moves.

Each constituent instructional act will have its learning consequences. Moreover, the effectiveness of the instruction will depend as much on the combination of teacher actions as on the individual acts. We look to neuroscience to help understand the learning consequences of particular teaching acts but any recommendations for classroom practice will need to take into account the social organisation of those acts and the integration of the subsequent learning products into complex student classroom performances.

Attempts to study students' metacognition have been limited by individuals' capacity to describe their thought processes. Wilson and Clarke (2004) demonstrated these limitations by eliciting students' descriptions of their thought processes while attempting mathematical tasks and then providing the opportunity for students to amend their descriptions while watching a video recording of themselves during the process of completing the mathematical tasks. In every case, students made substantial changes to their accounts of their thought processes after viewing the video. Video-stimulated reconstructive interviews can provide an additional source of explanatory or corroborative detail. Essential to the use of this methodology is the question of how similar are the thought processes stimulated by the completion of a task, the act of describing the completion of a task from memory, and the act of describing the completion of a task as a narrative annotation of a video recording. Neuroscience might usefully distinguish between the nature of the thought processes employed by students while solving a mathematical problem and the thought processes employed by the same students when reflecting on their problem solving, with and without the additional stimulus of a video recording of themselves completing the problem.

WORKED EXAMPLES AND GUIDED EXPLORATION

The use of worked examples, in which the teacher leads the class through the process of solving mathematical problems, is widespread in mathematics classrooms across cultures. Even within Confucian-heritage cultures, such as China, Japan and Korea, significant differences exist in pedagogical traditions, and the level of student spoken involvement in such worked examples has been shown to vary between classrooms. Recent comparisons of the practices of selected classrooms in Shanghai, Seoul and Tokyo (all Confucian-heritage cultures) revealed substantial differences (Clarke, Xu & Wan, 2010; Xu & Clarke, 2013).

With respect to the nature of the mathematical tasks employed, the Korean classroom was characterised by student attentive (but passive) observation of the teacher's completion of worked examples. The Shanghai classroom involved extensive public discussion of worked examples, emphasising correct use of mathematical terminology. The Japanese classroom placed much greater emphasis on student exploratory completion of mathematical tasks that had frequently not been modelled as worked examples by the teacher. Student engagement in such guided exploration is illustrated in the following conversation between two Japanese students engaged in dyadic problem solving.

Kawa [to Wada]: I managed to draw that line!

Wada: Like this?

Wada [to Kawa]: If you draw that line over the *middle point* [mid-point], isn't that the answer, Kawa?

Kawa: Oh, I don't think so!

Wada: I think you don't have to do such a thing. I think you just have to draw a line from *P*.

Kawa: I don't really understand what you mean.

Wada: Um, you drew a *middle point* [mid-point] here, right? So if you just draw a line from here, wouldn't that do?

Kawa: Can you draw a line from *P*?

Wada: Yes. If you draw a line from there, if goes over the *middle point* [mid-point] so there is no problem there.

Kawa: What was the name of the *theorem* again?

Wada: *Middle point* [Mid-point] *connection theorem*.

Kawa: That's it! But it isn't *parallel* there. Are you going to try drawing it there?

Wada: Draw a *parallel line*.

Kawa: Did so.

Wada: Well, it's not going over *P* if you notice.

Kawa: And which one's the same here? Tell me.

Wada: These two are *parallel*.

Kawa: Where's the *bottom line* [base] then?

Wada: This is the *bottom line* [base], I bet. God, I don't know which one is the *bottom line* [base] now.

Kawa: This one has to be the *bottom line* [base].

Wada: This has to be the (height), this one. This is the *height*. I got it now!

Kawa: Is this the *height*? Is it all right if it's now *parallel*?

Wada: Well, it doesn't have to be *parallel*. No need for that.

Kawa: But then which two become equally in half?

Wada: What the hell are you saying?

Kawa: Aren't we doing the one that we have to divide in half or something like that?

Wada: Yes, that's the one we're talking about.

Kawa: I'm starting to get mixed up now.

Wada: Well, I'm starting to get a headache. (Sample student–student 'private' interaction – Classroom transcript, Learner's Perpsective Study, Tokyo School 2 – lesson 2, 29:46:12 – 33:15:19.)

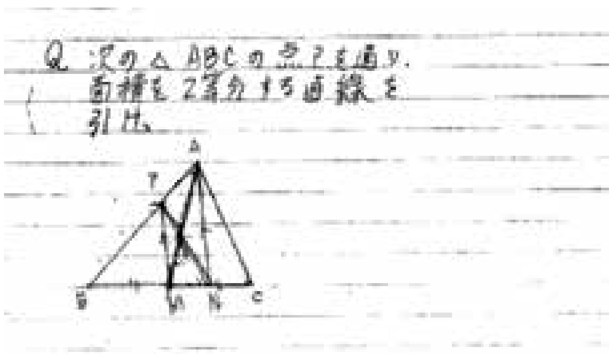


Figure 3a Wada's work

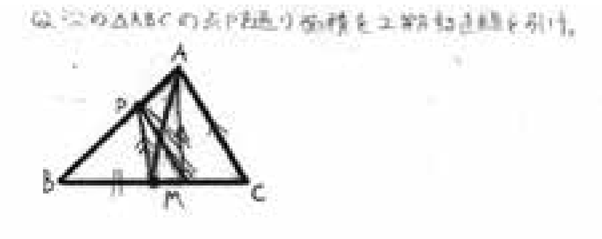


Figure 3b Kawa's work

In Figures 3a and 3b, we can see the problem representations constructed by each student. Such representations have their own role in the learning and problem-solving process and warrant specific investigation. Such dyadic interaction is a social performance with the purpose of completing a given mathematical task or problem. The nature of student cognition during such interaction warrants much closer study for several reasons:

- the difference between individual problem-solving and dyadic problem-solving as facilitators of student learning distinguishes important pedagogical alternatives in widespread use
- the learning consequences of student observation of a worked example by the teacher compared with the student's use of a taught procedure to solve a familiar problem, compared with a student's attempt to develop a procedure to solve an unfamiliar problem require detailed empirical explication
- explanations of reasoning provided by students (as distinct from teachers' explanations) were identified as significant by students in all cultures in which such explanations occurred.

A very different instructional approach employed in the Czech Republic integrates both the apparent power of the worked example and student explanation. In mathematics classrooms in the Czech Republic a common instructional event at the beginning of lessons is a practice known as 'oral grading'. This involves selected students completing mathematical problems related to the current topic on the board in front of the class, while being graded by the teacher. The students are required to write their solution methods on the board and explain the process they are working through to their fellow students. The purpose is for the teacher to determine students' level of knowledge. The teacher of Czech Lesson 1 from the TIMSS 1999 Video Study (public release collection) noted in her commentary:

> *None of the students know which one will be called up to the board. I want them to present their knowledge by commenting, explaining to their fellow students, and writing it on the board.*

While the selected student works on the problem set by the teacher, other students in the class work on the same problem at their desks. Those students may work independently or follow the student working at the board. Teachers regard this time as an opportunity for all students to engage in review. It is our contention that this strategy provides a powerful stimulus to learning through its combination of the worked example and student explanation, both of which have proved demonstrably effective in our studies of Asian classrooms.

Neuroscience may be able to assist in distinguishing the forms of learning (in neurological terms) arising from differences in student experience in classrooms such as these and also provide explanations for the relative effectiveness of such different instructional strategies in producing particular learning outcomes.

CONCLUSIONS

In this discussion, we have attempted to illustrate some of the challenges confronting those interested in researching learning in classroom settings. The examples were chosen because they highlight significant findings arising from sociocultural classroom research and seem to us to be amenable to further investigation using the tools of neuroscience. At the same time, each example offers significant methodological challenges if it were to be investigated from a neurological perspective. In each example, the complexity of the social situation is evident. If we think of the sociocultural and neuroscience perspectives as offering complementary accounts of such complex social phenomena, then it is clear that we are connecting very different research paradigms.

The techniques of neuroscience inevitably require a high level of specificity of research design with respect to the stimuli provided to the learner and the form in which any consequent learning can be recorded and interpreted. By contrast, consider the sort of complex social phenomena illustrated in this presentation:

- the role of the learner's spoken participation in classroom discourse in mediating learning
- the strategic, structured sequence of instructional acts, supported by selected artefacts, that, in combination, constitute a learning activity or a lesson
- the nature of student thinking when engaged in problem solving, undertaken as members of dyadic or small group social interactive units and the learning associated with this activity
- the function of both student explanation and worked examples, separately or together, in triggering student learning responses.

Our interest in these particular classroom examples is a direct consequence of the consistent significance attributable to each classroom phenomenon across a variety of cultural settings.

Such sociocultural phenomena cannot be meaningfully reduced to component instructional acts if our goal is to understand learning consequences of complex instructional activities, reflective of coherent, connected and culturally situated systems of pedagogy. If our aim is to identify the neurological consequences of each separate instructional act, then it may be possible to identify the key characteristics of such instructional acts with sufficient precision as to make each characteristic the focus of a clinical experiment designed to identify the learning consequences of the particular act in terms of either brain activation or neural networks. It is entirely possible that the effectiveness of the activity as a whole does not derive from the individual acts but from the cumulative interaction of their sequenced deployment by a teacher cognisant of the needs and capabilities of the particular learners. Nonetheless, while the neurological consequences of the disconnected instructional acts may not (even in combination) provide a coherent explanation for the effectiveness of the aggregate instructional activity, it is possible that neuroscience may have something to say about how the learning mechanism associated with each act and the means by which its effects might be optimised.

A challenge for any research project seeking to connect sociocultural research with neuroscience is how to interweave the complementary accounts provided by each analytical approach. We suggest that, in the same way that the unit of analysis is different between sociocultural and neuroscience research, so the nature of the explanations provided will be fundamentally different, offering not different explanations of the same phenomenon but explanations of related phenomena that are different in scale, in complexity and in the relative prominence given to the individual as cognising agent or as participant member of a social group. We anticipate drawing on the findings of one discipline to explicate, elaborate and explain learning as it is conceived in the other discipline. In studying instruction and learning in different classrooms around the world, we have found that the tensions and apparent contradictions that appear to pose the greatest challenge for useful interpretation and instructional advocacy also provide the greatest insight. A research partnership between sociocultural and neurological approaches should generate similar challenges, which on close examination will be seen as opportunities for significant insight into learning as a social and an individual phenomenon.

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