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Talk in Mathematics: teachers collaboratively working on developing students' mathematical language use in lessons

Jenni Ingram, Nick Andrews and Andrea Pitt

University of Oxford, UK

Talk in Mathematics is a collaborative project with two mathematics departments investigating ways of enabling students to develop their mathematical talk during lessons. During the project the mathematics teachers videoed their own teaching and chose clips to share in the regular group meetings. In this paper we outline three aspects of classroom interaction that received particular attention during the project: mathematical explanations; silence and wait time; and mathematical language. We examine the scope and depth of professional learning afforded by the approaches we took in the project and explore the wider implications these have for teaching and learning of mathematics.

Keywords: classroom interaction; explanations; wait time; vocabulary; teacher development; discipline of noticing.

Introduction

Opportunities for students to talk in mathematics classrooms has an important role to play in developing students' thinking and ability to communicate mathematically (Prediger & Erath, 2014). Research into promoting student talk in classrooms has largely focused on questions or prompts that teachers can use to encourage and support students (Franke et al., 2009) or on the social norms that need to be established to enable fruitful discussions to occur (Mercer & Sams, 2006). In this paper we describe how two mathematics departments used a video club to work on developing their students' mathematical talk in their lessons. Over the two years of the project the teachers focused on three aspects of students' talk: explanations; pausing; and their use of mathematical vocabulary.

In this paper we address the question of the scope and depth of professional learning afforded by a video club that is driven by the concerns and priorities of the teachers themselves. Reflecting the responsive nature of the project, the structure of this paper differs from that usually found in academic papers. Whilst we include a discussion of the research methodology and the way that we worked with the teachers, there is no specific literature review section. Instead the literature is introduced within each section of the paper as and when it is relevant, such as in the analysis of the teachers' conversations during the video club and the discussion of findings arising from the examination of the teachers' lessons.

Research Methodology

The findings reported in this paper come from a larger project titled *Talk in Mathematics* (TiM). Two groups of mathematics teachers worked with two researchers over a period of two years. The participants involved in the project changed over the two years as teachers moved school and other colleagues joined in. The data discussed in this paper is drawn from the teachers in the first school group (Kevin, Imogen, and Julia), and the second school group (Freya, Charlie, Emma, Anna, and Laura). There

were other teachers at some of the meetings, but as they did not attend regularly or share clips of their own teaching in the meetings they have not been included in the analysis shared in this paper.

The groups met regularly over the course of the project. Throughout the two years the teachers videoed themselves teaching or, within a school group, videoed each other. The teachers chose which class to video, when to video and what to video. All videos of entire lessons were shared with the researchers. Short clips from some of these videos were then chosen by the teachers to share for discussion during meetings. Some teachers only videoed one class whilst others shared videos of more than one class. This resulted in a collection of lessons covering the full age and attainment range, including mixed attainment year 7 classes, low attaining year 8 classes and A level further mathematics lessons.

The whole class interactions from these videos were transcribed using Jefferson transcription (Jefferson, 2004) and subsequently analysed by the researchers. In addition, all meetings were audio recorded and transcribed verbatim. The analysis of the data occurred on two levels: the classroom interactions within the videos were analysed using conversation analysis (Sidnell & Stivers, 2012), and when asked for this analysis was shared with the teachers. The meetings were analysed using thematic analysis. The initial codes for this thematic analysis were based on the foci identified by the teachers themselves as they introduced the video clips of their teaching within the broader topics of pausing, vocabulary and explanations. Further codes emerged inductively. This coding has allowed us a qualitative analysis of the scope of teachers' professional learning afforded by the project.

Teachers working collaboratively in a video club

Video-based professional development opportunities have been shown to have a positive impact on both teacher and student learning (van Es & Sherin, 2010). Most video clubs have focused on shifting teachers' attention from their own practice to their students' thinking. The teachers in this study broadened this focus to consider *how* students construct what they want to say, *how* they make use of opportunities to talk, and what resources they draw upon.

In each meeting one or two of the teachers would share a short clip from their teaching. This teacher would also set the focus of the discussion that followed. The meetings were based on the Discipline of Noticing (Mason, 2002), which combines reflective practice and action research. Through this approach the teachers shaped their own professional development opportunities through their choice of focus and consideration of associated actions. Mason (2012) asserts that through noticing aspects of our own practice we become sensitised to noticing this aspect in the future, which in turn gives us opportunities to act differently moving forwards. The initial discussion of the video clip was led by the teacher sharing the video and offering *accounts of* the interactions in the clip before *accounting for* (Coles, 2013; Jaworski, 1990) what was observed. Both the teachers and the researchers in the club would ask questions and prompt each other during the discussions, drawing on their experiences across the meetings and their own teaching. These conversations supported systematic reflection and noticing of different aspects of practice with the dual goals of recognising choices and possibilities for acting differently in the future (Mason, 2002, p. 70).

One aim of the TiM project was for research findings about ways of supporting and developing students' talk in mathematics to be addressed during the meetings in order to enable the teachers to use these in their own practice. In contrast to other

studies, this was primarily done by asking questions of the teachers about their own practice, as observable in their videos and in the discussions, in order to explore ways of acting differently or to consider what might constitute effective practice. In this way results and recommendations from research were not explicitly shared but the teachers were supported to draw upon their own expertise and knowledge of their classroom and their practice, in order to express these for themselves. Thus, the teachers constructed ways of acting differently that generally matched recommendations made in the literature, though the teachers did not use the technical language that researchers do. For example, the teachers explored aspects of using wait time (Ingram & Elliott, 2016), revoicing (Herbel-Eisenmann, Drake, & Cirillo, 2009; O'Connor & Michaels, 1993), scaffolding (Moschkovich, 2015b), the relationships and differences between semantic and lexical aspects of word use, and grammatical structures that are specifically mathematical (Pimm, 1987; Schleppegrell, 2014), but not using any of these specific words or making any reference to the research. To emphasise this point further, we would highlight that in the first meeting of the project where the teachers chose to focus on their use of pauses the researchers introduced the phrase *wait time* (a break between turns, as opposed to a pause that is a break within a turn), but this term was not taken up by the teachers who continued to talk about *pausing*.

Findings

The preliminary findings are grouped by the three foci that the teachers chose to work on over the course of the two years: explanations, pausing and vocabulary. The analysis is ongoing and in this paper we focus on those findings that were presented at the BCME conference and that prompted questions from the audience. In particular, we offer evidence for the scope of professional learning afforded by a video club that is driven by the concerns and priorities of the teachers themselves and we indicate more tentative observations about professional growth (Clarke & Hollingsworth, 2002), that we express here as deep learning, in respect of explanations, pausing and vocabulary. Connections are made to existing literature where they resonate with the ideas that the teachers themselves focused. This reflects the projects' principle of reference to literature arising from what the teachers identified as issues or strategies, rather than the literature directing what the teachers discussed or enacted in their teaching.

Explanations

Our analysis of the scope for professional learning afforded by a video club highlighted two key areas associated with explanations that emerged through the project. The first area that teachers discussed was the nature of prompts and tasks that led students to giving explanations. The second was what the teachers counted as an explanation and more specifically a mathematical explanation. The second area is more fundamental that the first, and emerged from a shift away from the initial focus on practice to a focus on beliefs.

There was particular depth to the first focus on the nature of prompts and task through consideration of examples other than those that explicitly asked students for an explanation. As researchers we examined the transcripts of lessons to identify scenarios where students gave these sorts of explanations and these are given in more detail in Ingram, Andrews, and Pitt (2018). These scenarios included where, without the teacher's invitation, a student refuted another student's response to a teacher question; in order to justify their refutation, the student had spontaneously offered this explanation. We describe these types of student explanations that are not explicitly

asked for by the teacher as *naturally occurring*. Extracts illustrating naturally occurring student explanations were shared with the teachers. Additionally, the teachers focused on using both pauses (discussed below) and tasks that would generate a debate between students so as to make naturally occurring student explanations more likely. One of the teachers subsequently focused on using tasks where misconceptions and multiple answers were likely to arise. Examples of her use of such tasks was evident in clips that she shared later in the project, but the focus of the discussions then was on the students' use of reasoning and mathematical vocabulary rather than the task choice (for details of this discussion see Ingram & Andrews, 2018).

The second focus on what the teachers counted as an explanation (and more specifically a mathematical explanation) occurred in two ways. Firstly, the teachers examined which student explanations they accepted in the clips they shared. Secondly, they imagined varying the content of these explanations in order to test the boundaries of what they might or might not accept. For example, explanations given by students included "because a hundred and fifty take away sixty is ninety", "because you can't", "because when it's in minus, numbers you take away get like a higher number". The teachers either attended to the reasoning within a student utterance or the language used as their criteria for whether something was acceptable as an explanation, with some explanations being accepted as mathematical by some teachers and not others. The question was raised as to whether a student referring to mathematical objects or processes using 'thingy' rather than the mathematical words was giving a mathematical explanation. While there was evidence from the meetings therefore that the scope of professional learning opportunities extended to beliefs about what constituted a mathematical explanation, further analysis of lessons is needed to identify whether these nuanced professed beliefs coincide with enacted practice.

Pausing

Pausing was the first area of focus identified by one of the schools and was the focus of the first three meetings with that school. We have already discussed how in the project pausing became a catch-all term for a range of strategies than involved the use of silences. Different teachers focused on different aspects of pausing during their interactions, but the scope of professional learning opportunities afforded by the video club included the areas of wait time, when it was appropriate to pause, and the issues around establishing pausing as a classroom norm. All of the teachers in this particular school group focused on the pauses they left after a student had given a response to a question, which Rowe (1986) named Wait Time II. We have reported elsewhere on this particular focus (Andrews, Ingram, & Pitt, 2016), including the importance the teacher placed on allowing students the opportunity to provide a fuller, or in another way revised, response. In the current paper we look at themes that the teachers returned to across the project. These include instances when the focus had shifted away from pausing, which might suggest more sustained changes to teachers' practice.

Previous research has detailed the difficulty teachers have in changing the time they wait after asking a question or after a student answers a question in a sustained way (Black, Harrison, Lee, Marshall, & Wiliam, 2003; Rowe, 1986) citing the uncomfortableness of pausing as a possible reason. The teachers in this study also experienced the uncomfortableness of pausing: "I was trying desperately not to look like it was uncomfortable so the kids didn't notice" (Charlie, meeting 2) and "I felt excruciating embarrassed and so did they" (Anna, meeting 3). Anna's

uncomfortableness seemed to be empathetic to the uncomfortableness of the students whom she saw as being placed "in the spotlight" by her use of pausing.

Different teachers found different ways of managing the uncomfortableness of pausing, establishing more refined strategies to promote fuller student responses than utilising Wait Time II alone. Charlie and Freya both talked about the nuances of *when* they were pausing (Ingram & Elliott, 2016) and focused on the types of question and forms of student response that would make leaving an additional pause appropriate. They talked about leaving pauses when they knew the students had an answer but just needed more time to articulate it. From the video data, this typically featured as part of a longer sequence of interaction that featured a strategy to enact Ingram and Elliott's (2016) Wait Time I(i) (time between teacher question and student response) as well as Wait Time II. In some cases, this Wait Time I strategy was to pose a question and allow students time to work on this individually on paper before taking in responses, with the students' writing providing the warrant for knowing that, given time, the student could articulate a response. Anna, on the other hand, did not talk about how the nature of the question or the students' responses might affect whether she paused or not. She engaged in what she called *displacement activities*, such as writing on the whiteboard or walking round the classroom, during the pauses she found uncomfortable. This was a strategy to allow the students the time a pause offers whilst minimising the uncomfortableness she felt leaving these pauses and relieving the pressure she perceived as being placed on students. These additional strategies of Anna, Charlie and Freya, although varying in their subtlety in terms of subject pedagogy, indicate a depth of professional learning beyond enacting pausing alone.

Vocabulary

Vocabulary was a theme that the teachers in both groups returned to over several meetings and that interacted with the other foci. A particular example of this was whether an explanation needed to include mathematical vocabulary and this was indicative of the depth of professional learning the video club approach afforded. A further indication of deeper learning was critical engagement with whole-school initiatives. Both the schools had a whole school focus on students' literacy and there were policies in place about sharing key words and explicitly supporting students to learn the technical vocabulary associated with specific curriculum areas. Sharing video clips of mathematics lessons brought these whole-school approaches into sharper focus.

Three key areas associated with vocabulary that emerged through the project indicated the scope for professional learning afforded by a video club. Firstly, there was a focus on assessing and developing the meaning students associated with particular words. Secondly, teachers discussed offering opportunities for the students to use technical vocabulary in meaningful ways (in the ways suggested by Moschkovich, 2015). Finally, consideration was given to the strategies that are effective in helping students to learn mathematics specific vocabulary, including making the distinction between learning nouns (such as expression and equation) and learning process words (such as simplify or solve).

Within the first area of interest, one teacher from each school, Kevin and Freya, separately and independently shared a clip where a student was having difficulty with the meaning of the word equation. In Kevin's clip a student asks "what's the difference between an expression and an equation?" and in Freya's clip the students are categorising statements written on the board into equations, expressions and identities and a student explains that "it can be an equation 'cause you add them all up and that's

an equation" and follows with "'cause an equation's with numbers and sums in it" and "an expression is with algebra". The sharing of these clips both resulted in an exploration of the choices between teachers giving definitions and students working from these, and giving students experiences where they can develop their own meanings and lead towards a definition consistent with one that would generally be accepted in the mathematics community. These discussions arose even though in both clips shared the teacher ended the discussions by defining equation and then moving on to a new task or word. Freya in particular wanted to explore ways of acting differently, but faced a dilemma as in her clip the student had developed alternative meanings for equation and expression that would not generally be accepted and correcting this was the only action that came to mind in the moment.

Emma shared a clip where the students were debating, giving reasons for their answers. Over time they shifted to using the mathematical word *multiple* within their reasons after prompting from the teacher, but were unable to do the same with the word *factor*. The intention here was that the technical vocabulary was introduced at a time when it could be used meaningfully by the students to support their reasoning. This clip was brought to the meeting by Emma in order to unpick the differences between the two scenarios where in the first case her support to use the mathematical language of multiple was successful, and in the second case this was not successful (described in more detail in Ingram & Andrews, 2018).

The focus on learning mathematical nouns as opposed to verbs was not addressed in a sustained way in the meetings. The teachers involved in the project did not share any clips with an explicit focus on the difficulties of students understanding grammatical aspects of mathematical language. However, the issue was raised by several of the teachers in several of the meetings. Freya in particular was concerned that her students have difficulty understanding phrases such as 'show that', 'find' and 'solve' and that these difficulties underlie obstacles they experience decoding examination questions more than the actual mathematics involved. As with the themes of explanations and pausing, professional learning here was deeper than offering opportunities in lessons for students to experience technical language alone and included introducing carefully constructed situations in which it was more likely that students would choose to the technical language themselves.

Conclusion

In this paper we have presented preliminary analysis from a two-year collaborative project where two groups of mathematics teachers worked on improving their students' talk within mathematics lessons. Our analysis to date of the meetings and the videoed lesson indicates the scope of professional learning afforded by a video club that is driven by the concerns and priorities of the teachers themselves. The breadth of ideas explored within several key issues related to student talk in the current project in encouraging. Yet the analysis presented in this paper is ongoing and any conclusions we might draw about the professional growth with respect to the ideas raised at this stage are cautious. We have evidence of connections between the discussions held in the meetings and the practice observable in the videos given to the researchers when focusing on teachers' use of pausing, but not for the other two issues identified in this paper of explanations and vocabulary. Whether the ideas that come to mind for teachers in meetings also come to mind in the midst of a lesson remains uncertain. Furthermore, not all the specific issues of focus in the meetings beyond these three have been examined. The analysis so far has been driven by those aspects of talk on which the

teachers within the project particularly focused. Conversation analysis in particular is an approach which also enables us to examine more implicit aspects of practice that we have not yet fully made use of.

The focus on vocabulary is particularly interesting in terms of the opportunities for deeper learning through critical engagement with whole-school initiatives. Whilst the teachers and the researchers talk about a need to situate vocabulary learning within wider mathematical practices, the school-initiated professional development opportunities the teachers were offered and the school policies within which they were working emphasised distinct approaches that specifically focused just on learning vocabulary. Wessel and Erath (2018) suggest that these two approaches of learning and using vocabulary need combining with explicit teaching strategies embedded within broader meaningful discursive practices.

A challenge of working in this way with a group of experienced teachers is the need to be responsive to what the teachers notice and attend to as they examine their own practice (Coles, 2014). Whilst most video clubs are established with a view of changing practice, it is not always the case that certain aspects of practice need or are wanted to be changed. The teachers in this project noticed aspects of their practice that they wanted to change but also aspects that they felt were effective at accomplishing what they were aiming to achieve. Both these situations give rise to a growing awareness of ways of acting differently.

The early findings suggest that the way of working with these teachers may support sustained change in practice, which is not dependent upon the presence of the researchers and theoretical ideas they can offer. Rather a supportive community or change environment (Clarke & Hollingsworth, 2002) in which to examine your own practice in detail and to consider ways of acting differently is key. This enables teachers to apply strategies that resonate with those established through academic research effectively within the context of their own classroom, with the motivation and focus for change coming from the teachers themselves. This raises a challenge of how to effectively use an approach to professional learning which draws extensively upon teachers' existing expertise to enable sustained change in areas of practice identified by researchers. For deep professional learning, from the perspective of Clarke and Hollingsworth (2002), is shaped by teachers' goals, beliefs, knowledge and practice alongside external influences such as research findings and school priorities, as well as the context within which the teachers are working. The approach adopted in this project brought to the surface teachers' beliefs and goals, and supported teachers' professional growth through systematic reflection between these beliefs, goals and their practice alongside enactment of new practices prompted by their school's priorities.

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