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A case study of the use of the mathematical register by Year 8 students: a critical analysis of teaching strategies that can be employed to encourage this use.

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Abstract

The quality and variety of mathematical language that pupils hear are identified in the new curriculum as key factors towards developing their mathematical vocabulary. This project explores, using a case study methodology, the concept of mathematical language and specifically the mode of speech we use when we talk mathematically. The participants were a class of higher-attainment 12-13 year olds in a UK comprehensive school. A case study methodology was used to examine pupils' prior attitudes to mathematical talk and to analyse strategies for improving it. This study involved a combination of pupil and teacher interviews, lesson observation, and analysis of learner product from these lessons. The key finding was that student attitudes towards mathematical talk (and their acceptance of it as a valid mode of discourse for them) are a key factor in their ability to use mathematical talk well.

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Introduction

In this research I investigate the concept of the mathematical register, and ask questions about how students can learn to use it effectively and hence improve as mathematicians. I chose this topic because language and communication have always fascinated me as wider fields of study, and in the early parts of my initial teacher training I found myself becoming more and more aware (via reflection on my own teaching) of the distinctive mode of speech that I used as a mathematician. I was interested in tying down exactly what people meant when they spoke about mathematics being a ‘language’, because I thought this was a powerful subject to explore.

The broad issues relating to this topic are about whether or not this concept of a mathematical register is a useful one – where by useful I mean ‘provides a good framework to talk about developing student’s mathematical speech’ – and how the relevance and power of it can best be communicated to students such that they can access it for themselves.

I decided to investigate this topic via a case study with a high-attainment year 8 class with whom I was working. They were a useful class for this study for logistical reasons (for instance, my mentor was also their class teacher) and also because they had had a prior focus on developing mathematical talk, so this would not be a new idea I was bringing to them – this would make it particularly appropriate to implement a case study methodology, where I could study them in their existing context.

My own thinking on this topic did change over the course of the research, and the text of this study reflects that. I start, therefore, by setting out the initial research base from which the ideas for this study’s methodology and research instruments arose, and give a review of this past literature. I outline the research questions that arose from this review.

I then go on to expound further on the methodology of the study, highlighting my ethical considerations and the details of my research collection. After that, I begin a presentation of the findings of the study. The reader will find the focus of the study shifting onto different parts of my research questions, which reflects how my own thinking on this subject developed during the process of carrying out this research. The conclusion of the report outlines avenues of further thought on which further research could be productively based.

A review of the literature on the mathematical register as a concept within pedagogy

What is it that we mean by the term ‘mathematical register’? What follows is a brief discussion of its history and development as a concept, and then an explanation of its relevance outside of a theoretical linguistics discussion. I also go on to discuss the multi-semiotic nature of mathematical knowledge constructions, and the impact that this has had on the intended scope and focus of this research.

I then look in general at the importance of effective mathematical communication– as opposed to the specific notion of the mathematical register – as a presence in the classroom, and outline why strategies to encourage pupils to communicate mathematically are believed to be key for their understanding. I then go on to illustrate some proposed routes towards these strategies.

Critical engagement with these, in context with the wider literature on teaching and learning approaches, forms the basis for the particular professional concerns which this research seeks to address. Viewing the preceding holistically, I identify the key questions that I want to answer with this research.

The mathematical register

The mathematical register as a term originates with Halliday (1978): he defines a register as “a set of meanings that is appropriate to a particular function of language, together with the words and structures which express those meanings” (p.195). Hence, the mathematical register is the particular set of meanings, words and structures that we use to express mathematics. As Pimm (1987) makes

clear, it does not refer just to the technical terms of mathematics alone, but also to the particular phraseology and structure of discussion that is characteristic of it.

An example that Pimm (1987) cites of this is the use of the word ‘any’ in a mathematical context. Consider the sentences ‘Is there any even number which is prime?’ and ‘Is any even number prime?’. The first is unambiguous – yes, 2 is – but the latter carries ambiguity. In ordinary language, ‘is any X, Y’ would here mean ‘are there any examples of an X such that for that X, Y’: it asks for a particular example. Mathematicians would normally use ‘is any’ to mean ‘is it true that for any X we care to mention, Y is true’ (not all even numbers are prime, so the answer is no). The mathematical mode of speech is different from the ordinary. This also nicely illustrates why the concept of a mathematical register is not important merely because it allows linguistics classification: in fact, understanding the nature of mathematical speech actually aids our ability to communicate mathematically.

The multi-semiotic register

Schleppegrell (2007) develops and extends the notion of the register to not just include written and spoken language: instead, she points out that mathematics uses a variety of semiotic systems in knowledge construction: “symbols, oral language, written language and visual representations such as graphs and diagrams” (p.141). The concepts of mathematics can be difficult to express in ordinary speech, and hence mathematics has built up a rich system of visualisation which is part of the register of mathematical communication but is not specifically mathematical language. Schleppegrell claims that meaning is constructed in the intersection of these four things. This claim seems convincing: it is a rare part of mathematics that does not admit some use of symbology and of visualisation as an aid to understanding.

It is for this reason that the topic chosen as the teaching focus for this project is mathematical constructions: it is an area where all four of Schleppegrell’s (2007) components of the mathematical register are exemplified. There is much more literature with an emphasis on mathematical language as opposed to the other two components (symbology and visualisation), and the small scope of this research means that its focus will be on the language use aspect of the register, in order to utilise this wider research base: however, the other factors will not entirely be set aside. While it is clear that a multi-semiotic view of the register can be an important tool – Temple and Doerr (2012) use it

to great effect in their study of the development of the register in one teacher's classroom – it is one that requires a more detailed and nuanced approach than this research can provide.

The importance of mathematical language to teaching and learning

At the end of Adams' (2003) discussion of the similarities between mathematical literacy and print literacy, she takes the position that the very things that give mathematics a framework and power as a discipline and body of knowledge – its “words, numerals and symbols” (Adams, 2003, p.786) – are the same as those that students must use to communicate, explain and solve within their studies. In other words, “a knower of mathematics is a doer of mathematics, and a doer of mathematics is a reader of mathematics” (Adams, 2003, p.794). Hence, helping students towards effective use of mathematical language is part and parcel of helping their understanding: one cannot extricate mathematics from the register in which it is communicated.

The new National Curriculum of England is also very clear on this matter, and provides solid justifications for why as mathematics teachers the development of mathematical language forms a key part of our teaching:

The quality and variety of language that pupils hear and speak are key factors in developing their mathematical vocabulary and presenting a mathematical justification, argument or proof. They must be assisted in making their thinking clear to themselves as well as others and teachers should ensure that pupils build secure foundations by using discussion to probe and remedy their misconceptions. (DfE, 2013, p.3)

It should be noted that the curriculum here is differing from its perspective on language from the texts already examined. The curriculum's view is on mathematical language as a skill: a skill as part of a panoply of other mathematical skills, perhaps. This is different from the perspective of Schleppegrell (2007) who, as discussed, views mathematical communication not just as a skill within mathematics but as the foundation on which mathematical knowledge is constructed. Additionally, the curriculum places an emphasis on mathematical vocabulary.

Vocabulary, language, and register: clarifying terms

However, as discussed above, vocabulary alone is not what sets a piece of communication within the mathematical register. Moschkovich (1999) examines the practice of a teacher teaching English language learners (what would be called in the UK ‘English as a Second Language’ students). She found that the teacher “did not focus primarily on vocabulary development but instead on

mathematical content and arguments as he interpreted, clarified and rephrased what students were saying” (Moschkovich, 1999, p. 18). In other words, he focused more on helping students construct their mathematical knowledge through discourse and discussion. The focus was not on the particular grammatical or vocabulary errors of the students: the teacher worked to understand the pupils despite these errors. Instead, it was on the meaning behind those words. We can still say these students were speaking mathematically, despite imprecise use of the technical vocabulary, because it is the set of meanings and structures that define the register of mathematics, and these were being accessed.

It is interesting to consider an aspect of Huang, Normandia and Greer’s (2005) observations from their case study of another effective practitioner. Ms G, the teacher they studied, had a large emphasis on getting students to teach the class and explain their ways of solving a problem: again, an emphasis on developing the students’ ability to talk mathematically. However, she was also “particular about having her students use the terms and jargons accepted in the field of mathematics” (Huang et al., 2005, p. 38). She saw this as a mechanism to “socialize students into the discourse of school math” (Huang et al., 2005, p. 38).

This should give us pause for thought: it gives us a way to synthesise the perspective of the national curriculum’s emphasis on vocabulary with the literature’s emphasis on developing discourse. There is a sense in which it is clear that vocabulary is not what makes mathematical speech mathematical: if accident of history had decided on different invented words for some mathematical terms, the meaning would be retained. However, it is important that students also learn to use jargon and vocabulary in a standard way, because it allows them access to a common understanding and learning community. Language is not private: the common mathematical register exists as a mode of communication between people. The power of vocabulary comes in unlocking students’ ability to understand and engage in dialogue between mathematical texts and their peers and teachers.

A wider overview

An effective summary of the above can be found in Morgan, Watson and Tickle (2004). They imagine two classrooms which exemplify the particular norms they see as being important – to construct, or to avoid. They contrast ‘classroom A’, where pupils “see mathematics as a social activity in which meaning is constructed through collaboration.” (Morgan et al., 2004, p.83), with ‘classroom B’, where “the teacher maintains social control and is totally in charge of the direction

of the lesson. The construction of mathematical meaning is a private matter.” (Morgan et al., 2004, p.83).

Morgan et al. (2004), although they elsewhere do express a preference for the norms of classroom A, do not necessarily reject the construction of a private meaning. However, as discussed, the literature on mathematical language supports the idea of mathematical understanding being achieved more effectively through discourse. This notion of meaning construction is an important one. It is the reason for our focus on the mathematical register: effective use of it is, it seems, a route to effective construction of mathematical meaning.

Some professional concerns that naturally arise from the above discussion are clear: how can teachers most effectively induct their pupils into effective mathematical communication? How can teachers modify their own mathematical language use during discussions with pupils in order to aid this induction? How can socialization of students into the discourse of mathematics be achieved? How can students become fluent in the mathematical register?

Routes towards developing fluency: the work of Temple and Doerr (2012)

Temple and Doerr (2012), in their study on the development of students' fluency in the register, identified two kinds of strategy the teacher employed in pupil interaction, dependent on the goal of the lesson. When the goal was for the students to work with the teacher to construct new knowledge, the teacher employed focusing and probing tactics in their speech to push students to “explain their thinking and build on each other's contributions” (Temple & Doerr, 2012, p.301). Particular tactics that the teacher used included feeding back directly with justification and clarification requests: when pupils expressed something using natural or symbolic language that did not make sense to the teacher, the teacher pushed them to re-clarify and negotiate exactly what they were trying to express. The focus was on a development of the pupil's own thinking and communication: in other words, the mathematical talk done by the teacher was minimised.

However, in lessons which aimed for students to talk about things they had previously learned – perhaps building on a previous lesson of the first type – the teacher's discourse had a ‘funneling’ quality: it encouraged “the accuracy and precision of expression more than exploration or explanation” (Temple and Doerr, 2012, p.301). The teacher employed more repetitions and recastings of pupil contributions during these lessons. There was less emphasis on encouraging

students to explore their reasoning, but more on helping them recall and clarify previous conceptual and linguistic knowledge. The teacher's use of mathematical talk was more active than in the other mode of discourse: they still made use of clarification requests as before, but they were also accompanied with more feedback on the particular ways to say things. Understanding, having been initially constructed in the first type of lesson, was being refined and built upon.

Both modes that the teacher used seemed to support the students' development of register fluency, Temple and Doerr (2012) concluded, albeit in different ways. The 'funneling' strategies and the 'probing' strategies both had their place: indeed, their study sought to show the two approaches not in opposition but as two different strategies to be employed depending on the goals of the lesson or episode within a lesson.

Conclusions from a review of the literature towards my own work

The findings of Temple and Doerr (2012) will form the basis for my own research. They claimed to have confirmed and extended the results of others in their findings; I want to build on the work that they did and use the notions of 'funneling' and 'probing' strategies (and the tactics/'moves' used within them) as a framework for examining the effectiveness of different teaching strategies at developing effective use of the mathematical register. I also want to examine the existing perceptions of students towards mathematical language. I am interested to the degree to which students are aware of their own use of the register and of the notion of mathematical speech at all. Finally, it will be useful to consider (and here the multi-semiotic view of the register from Schleppegrell (2007) will be used) the degree to which a focus on developing effective use of the register assists in students' understanding of the chosen topic, geometrical constructions.

From these considerations, three research questions arise:

RQ1: What are the perceptions and views of students towards mathematical language?

RQ2: What teaching strategies are effective at developing students' fluency with the mathematical register?

RQ3: How does an emphasis on mathematical communication affect students' understanding of the topic of geometrical constructions?

Study purpose and methodological approach

I knew that I would be working with '8m1', a class of high-attainment Year 8 pupils. This group was chosen primarily for scheduling reasons, but also because their existing teacher was already interested in developing their ability to communicate mathematically. It was an interesting setting in which to undertake the study: importantly, also, it was not a setting I was going to create for the purpose of the research. While some of my own teaching would form a key part of the research, it was not about creating a change and evaluating and reflecting on the result. Rather, the nature of my research questions, especially RQ1, meant that what I needed to understand was the context and setting of the class's existing understanding of mathematical speech. My goal was to slot the teaching I was doing as part of the data collection neatly into the existing context.

For these reasons, I decided to take a case study approach to the design of my study. Denscombe (2007) suggests that the defining feature of the case study methodology is its focus on a particular object of study. It is about getting an understanding of the relationships and processes underlying the case, and finding a holistic viewpoint. This was exactly the nature of my investigation.

While I wanted to see how a focus on the mathematical register affected student understanding, the study was not about evaluating and feeding back into my approach – I was not looking to find the best way to effect a particular change. If it had been, I might have considered an action research approach. In the planning stages for this research, I considered an action research approach focusing more on my trying out new things and observing change – in the end I moved away from this idea. One reason for framing this research as a case study was also because the literature base I was drawing from also generally took a case study approach: hence this seemed appropriate to preserve continuity and allow more direct comparisons between the studies.

Data collection: methods and justifications

The plan for my data collection came in three parts. Firstly, I wanted to engage in some semi-structured interviews with their regular class teacher, and with 6-8 students which I would choose from the class. The interview with the teacher was designed to get a picture of his thinking and thoughts on the prior understanding that the class possessed. It was also designed to provide evidence and detail on the class' prior learning and prior work at learning to use the mathematical register. The interviews with the students were designed to directly address my first research

question. I was interested in the degree to which students perceived a difference between mathematical and conversational speech. In these interviews, I generally had specific points I wanted to cover, but I knew that things would be raised or mentioned that would lead me away from these initial questions. It seemed appropriate, therefore, for the interviews to be semi-structured. As Denscombe (2007) points out, there is a continuum between semi-structured and unstructured interviews. I undertook to start with structure and a clear outline of the points I wanted to cover, taking a more semi-structured approach: however, I was ready to step away from that structure if that would serve my inquiry.

One issue with the heavy focus on interviews was that I would – via my questioning, introduce a bias into the results, forcing the participants down a particular thought-path and hence creating the results I wanted. I do not believe, in practice, this was an issue: although my questioning was ‘on-topic’, I was careful to not lead participants too much. In the end, a lot of the more interesting parts of what the students said in their interviews came from spontaneous discussion between them spiralling from my initial questions - and I treated these parts with the greatest weight - so as long I was careful in my interpretation, I reduced the impact of my bias on the data.

The second piece of data collection was the observations by the teacher of the lessons that I taught around the topic of construction. This was to be a focused observation, looking at specific aspects of my teaching. The Appendix from Temple and Doerr (2012) served as a framework for this observation. Any observation carries with it a degree of interpretation, and so a degree of specificity was required in what I asked the teacher to observe. I wanted to evaluate the specific teaching strategies I was employing. The language the framework provided gave me specific pointers in planning the lessons on the techniques I could employ. The teacher’s role was to observe my use of these techniques. In this way, I undertook to add a systematic element to the observation. I asked him to look at and keep track of instances of their use, and also evaluate their effectiveness. The rationale for evaluating the lessons through observation rather than self-reflection was that it is very difficult to observe something specific like language use while it is occurring. The teacher, as an objective viewer, could evaluate the effectiveness, or at the very least provide me with the information I would need later to evaluate the lessons, which I set out to do in the data analysis section of this assignment.

The final piece of data collection I needed to take in was the student product in the class, both previous to my teaching and that produced from one of the lessons that I would teach. In the former case, I made brief notes for each specific student that I had already interviewed. Due to the limited scope and size of this study, I knew that I would not have time to fully review and take copies of each student's workbook for later: hence the plan was to restrict what I looked at and make summary notes for each. This does mean that I necessarily had to interpret and filter the student's work during data collection: however, it meant a much quicker data collection process without disrupting the useful content garnered. I also took in the product of the lesson on performing the basic geometrical constructions. Students were asked to produce A3 sheets summarising at least one of the constructions. They were not given instructions in words for the constructions, so they had to formulate the constructions for themselves. Analysis of this product meant I could directly address the second and third research questions.

In summary, therefore: I used semi-structured interviews to answer the first research question by giving me a focused yet flexible insight into students' understanding of mathematical speech and their prior mathematical background. I used focused lesson observations with a systematic framework to collect information on the taught series of lessons on geometrical constructions: this allowed me to answer my second research question by providing analysis of which teaching strategies I used and which were successful. Finally, I collected learner product from the lessons, along with summaries of the previous work of students that I produced by looking at prior work. This provided documentary data to supplement my answering of research question two and to address research question three.

Ethical implications and subject selection

Before beginning data collection I had to consider the ethical implications of what I set out to do, an important first step in planning research. The core assumption when carrying out research should be that researchers are not in a privileged position above their subjects: hence, one cannot justify putting the interests of the study in front of the interests of the participants (Denscombe, 2007).

Denscombe (2007) outlines three key principles which should guide the actions of researchers. I will set out, for each in turn, how I addressed this principle in my research. These principles also align with the British Educational Research Association's (2011) own ethical guidelines, which I read and implemented within this research.

The interests of participants

Firstly, research should protect the interest of the participants. For educational research, this means that in specific there should be limited impact on the learning opportunities of participants. In my study, the ways in which my work could have impacted on the students' interests was two-fold.

Firstly, I carried out my interviews during lesson time, taking them out of the normal maths classroom. I had previously liaised with their teacher, and made sure that the time they were missing would not greatly impact their learning. Obviously they would miss out on some of the lesson, but due to the nature of the task they were missing, this was not a problem.

Secondly, I needed to make sure that I had confidence in the teaching strategies I was employing in my lessons. I was planning lessons using Temple and Doerr's (2012) work as a source for strategies: strategies that I thought I could use well, and which their study had found did work. I tried to teach the lessons I would have taught had I not been collecting data on that lesson – this relates back to my case study methodology: I was trying to teach lessons in line with pupil's normal experience. As such, the lessons were in the students' interests, rather than being counter to them.

As can be seen throughout this study, I have anonymised all participants in the interview stage. This is another aspect of protecting the interests of participants, by separating their contributions to the study from their identities. This means that their personal interests cannot be affected by their participation. The students are assigned the anonymising labels R, T, J, L, D and S in this report. Their class teacher, also my mentor, has been anonymised as 'the teacher' throughout.

Avoiding deception or misrepresentation

The second principle in Denscombe (2007) is the avoiding of deception or misrepresentation in a study. This was not an ethical issue I had to grapple with in this study: no part of it involved hiding or lying about what I was doing. Students were never asked to do anything or contribute to anything for any reason other than the reality. It is raised here only to acknowledge its importance.

Assuring informed consent

Finally, I needed to get informed consent for the participation of the students. I was told by my mentor, who helped me in the design of my study, that it was not necessary to seek permission from

every member of the class to carry out most of the study, because I was in the main not doing anything that would not come under normal expected behaviour as their class teacher.

What did require extra permission was the interviews. I asked students to volunteer for the interviews, explaining that they would just involve talking to me about maths and that the purpose was for 'university research'. When I had selected my participants, I made sure, before the interview was carried out, that they knew what I was going to use it for, what the context of the study was, and why the interview was a necessary part of that. All students were happy with this, and none expressed a wish to not be interviewed.

I should note also how selection of participants occurred: in the main I tried to pick students who had volunteered or expressed an interest in talking, or who I had thought would provide good contrasts to existing students. Three boys and three girls were selected, and each interview took place in a boy/girl pair. Students were selected from a similar attainment band: not a deliberate choice on my part, more a function of who volunteered or proved a promising interviewee, but I note it here nonetheless.

Strengths and limitations of my methodology

A key strength of my methodology was that it was realistic in scope. My plans for data collection would provide me with an amount of data which was not too onerous to analyse. I had a clear purpose in mind for each piece of data collected, which gave my study a focus. Interviews were perfect for the information I wanted to gather about student attitudes, because they meant I could be directed by the participants' responses.

A weakness was that all of my data was qualitative in nature. All of the analysis required subjective judgement on my part, and this meant I needed to work hard to not form conclusions before I had looked at my results. All of the analysis was filtered through me. Additionally, I lacked (primarily due to practical time constraints) any opportunity to follow up with the students I had previously interviewed after the lessons had been carried out, which would have helped provide more data towards answering the third research question.

My findings

Student consciousness of the mathematical register

In the initial interview with the class teacher, I asked him what he thought students would think of when I asked them about talking mathematically. He said that he would expect most to think of this as the vocabulary we use in maths, rather than the understanding that he, and this assignment takes: that the mathematical register is also defined by the particular modes of discourse and ways of argument that we use in mathematics. From a student's point of view, I would expect the latter view to manifest as an understanding that mathematical talk is about reasoning and explaining as much as it is about using the correct words.

In interviews, this hypothesis turned out to be broadly correct, with some exceptions. Student R and T were interviewed together. Student R was emphatic that there was a difference between mathematical speech and normal speech – however, she said that was because in maths you “have to say the right terms” (Student R, face-to-face interview), – by which she meant you have to use the right words. She cited examples like circumference, and square. Student T, in contrast, thought there was not a difference between how we talk in maths and normal speech. I asked them both if they thought of “justifying and explaining” (Interviewer, face-to-face interview) as a particularly mathematical thing: T said that in maths when he explained things, he would use maths words, but then this was subject dependent – in science he would use science words, in English he would use “normal English” (Student T, face-to face interview). One can interpret this to mean him referring to the particular jargon used: he uses the same types of explanations but in different ways. In the review of students' prior work, I found T's work very lacking in mathematical explanations. Often when asked to explain things he would report what he had done, but his ability to successfully use the mathematical register did not appear to be well-developed. Unfortunately, due to a missing exercise book, I did not have access to much of R's prior work – what existed appeared clear and well-written, with a more developed use of the register: but there was not much to go on.

For J and L, who were interviewed together, their interview often strayed from the subject at hand, and more into the relationship between the teacher and the pupil. For context, J and L are often some of the loudest voices in the classroom. Student L frequently speaks with no consideration of who else is speaking or whether it is a good time to speak. Student J is less of a problem in this

regard, but is often still a source of off-topic talk. However, they are two of the highest-attaining students in the class. Often, with L, she will seem to understand something but struggle to express it in a concise or clear manner. This was part of the motivation for choosing her as a participant

Their opinions of the distinction between ordinary and mathematical talk was coloured by a perception of the classroom as a place where the teacher is in control. They both expressed an artificiality with the set-up of mathematical talk in the classroom – when talking about this they seemed to be thinking mainly of whole-class questioning periods. Student J described these periods of questioning as “not like a free spoken conversation” (Student J, face-to-face interview) – he seemed to think there were rules and boundaries to it, but he did not have a positive opinion towards them.

I asked them what exactly they thought it was to talk in a mathematical way, and they both said it was using appropriate language – using particular “maths terms” (Student J, face-to-face interview). Student J cited the (recent) example of strong and weak, positive and negatively correlated scatter graphs. Again, it was particular vocabulary use that was identified as mathematical. Student J spoke in negative tones about teachers asking students to use these terms: his perception was, as he reported it, that if you tried to explain things without using particular vocabulary teachers would correct it you. For J, mathematical communication was perceived to be a constraint that was put upon him, rather than a tool he could utilise.

Interestingly, in the review of students’ prior work, J actually showed himself to be adept (and improving) at explaining himself with a range of techniques. He was clear and precise in how he set out his thoughts and explained things. He appeared to be using the register effectively, despite a lack of awareness of it.

Students D and S were the final pair interviewed together. Student S linked her ability to talk about maths to the degree she understood it twice during the interview. She also said that developing her skills at maths also developed her understanding and hence her ability to talk about it: she expressed a wish to be given more challenging work as a route to this. She said that talking mathematically was about using more facts or statistics or methods, and related the way we explain and justify things in mathematics as being similar to how this was done in other subjects – for example geography. For context, at the time of the interviews the class was coming to the end of a series of lessons on data handling and I think this was first and foremost in her mind. Student D was quiet,

both of the pair were, but D more of the two and as such it was hard to get much from him in interview. He said that you talked about numbers in maths, “which you don’t in real life” (Student D, face-to-face interview) – I was unsure how to interpret this statement. He did give a very clear idea of what it means to justify an idea in mathematics: he said that you had to give a convincing argument – to make the other person think it is right. This is a principle the class teacher had mentioned stressing in the classroom in his interview, and it was interesting to see D had taken this on board.

In terms of their prior work, D worked well – it was always clear he had tried hard – but often he seemed unsure how to word things and had shied away from extensive explanation. This reflects his interview in its reticence towards expression. Student S is another high attainer and this was reflected in her work: she gave very clear explanations of things in all such tasks. It was interesting to note that she successfully used the word “equivalent” (Student S, face-to-face interview) in a mathematical fashion when comparing two different sets of objects in a problem – this was quite a sophisticated use of mathematical language.

Technique implementation and responses to the multi-semiotic approach

In the lessons that were taught, students were mainly being introduced to new material. As such, testing the techniques of Temple and Doerr (2012), I planned to use mainly ‘focusing’ and ‘probing’ techniques in my feedback.

This was borne out by the observations. The move I used most often over the lessons was an evaluation move, asking students to consider the truth or otherwise of a statement. This was often paired with asking students to hypothesise: indeed, on the occasions in which they worked in groups (which happened in the third and fourth lessons) this was a key element of the students’ activities.

The worksheet used in the second lesson was successful at achieving the aim of getting students engaged and then developing their understanding. This sheet asked student to consider things like line and angle bisectors, mainly via their definitions as loci: but it did this in an informal way and before they had learnt these constructions. The aim was to set up and motivate our study of constructions which was to follow. Also paired with this was a discussion on how we could find the centre of a square. We discussed if this was still possible if elements of the square were removed, or

if we were not allowed to use a ruler to measure the sides, or a protractor to measure the angles. In this manner, my aim was to probe and focus the students towards the direction of the constructions, without employing funnelling techniques directly at this stage.

Lessons with multi-semiotic components and an analysis of learner product

In the following lesson, students had a video on repeat on the central board, which showed how to perform four basic geometric constructions. Their task was to, in groups, explain what was being produced in each construction, and produce their own written guide of how to perform it and to explain why it worked. Here, I was employing multi-semiotic techniques, using a visual display and asking students to translate this into words rather than giving them an explanation directly. The learner product I collected in was from this lesson. This was a ‘recounting’ move, in the language of Temple and Doerr (2012) – students were asked to put into words the steps required. The learner product from this task was very varied. Most students gave very physical descriptions of the task, although the video they were working from had stylised compasses and ruler. For instance, one student referred to the point of the compass consistently as the “metal tip” (seen in written work). For a few groups, their descriptions were solely instructional. Each step described a physical aspect of the drawing, for example “draw the line so it looks like a cross but keep it in the same direction” (seen in written work).

Some were more sophisticated in their language: the key phrases I was looking for when analysing the work were reference to lines colliding, intersecting, or crossing. The group that contained student L was the most precise in their language in this regard, and also used labels and diagrams to help explain their instructions in a multi-semiotic fashion. For context, it should be noted that this group also contained student B, who is the highest-attaining student in the class to a degree that he is an outlier in the distributions of levels attained.

Student T, who it will be recalled from the interviews did not greatly distinguish between conversational and mathematical talk, struggled with this task. He complained that he understood it, but that the nature of the group set-up was that he had to communicate this understanding to the rest of the group, and he found this difficult. He also found it hard to write down the explanation of his intuitive understanding of how the construction he was looking at was performed.

Student S's group were the only ones to attempt to give reasons for why a construction worked. They said that the line bisector construction works because it gives you "90 degree angles in the four sections at the cross in the centre" (seen in written work). This is not strictly correct, but it showed at least an intuitive understanding that the fact the line bisector is perpendicular is related to why it is the bisector.

Key overall findings and emerging issues

The first research question – on the perceptions and views of students towards mathematical language – has proved to be the interesting theme that ran throughout the findings. Generally speaking, those students who expressed more awareness of the distinction between mathematical talk and 'ordinary' talk were generally the ones who could more readily access the register skilfully. This is not to say that those who did not acknowledge the distinction did not use it, even as they perhaps lacked awareness of their own use. In the following discussion of the findings I will analyse exactly what I think this means, but it was a marked feature of the findings and the key issue I have identified so far.

On the matter of the second research question I think the findings are less clear. The interview with the class teacher on his own teaching techniques and the apparently successful deployment of similar questioning and probing approaches in my own teaching both suggest that these might be effective in developing the mathematical register. The interviews with the students, however, give us pause for thought. As the class teacher had thought, most students saw mathematical language through the lens of correct vocabulary use, even though this is not an idea he had particularly promoted within the classroom. This comes back again to the issue of student perception.

Finally, the focus on planning the construction lessons with a view towards developing mathematical talk rather than solely on the construction skills was seemingly a valuable one. From the learner product, we see that students came to their own understanding of how to carry out the constructions, and this was perhaps better than an approach where they just had a procedure explained to them. Unfortunately, I do not have any further data on their retained understanding, and it would be interesting to go back and see whether encouraging them to develop their own language of constructions has helped in longer-term understanding of this topic: this is beyond the

scope of this research, however, and so the third research question may have to remain unresolved in the most part.

A discussion of the above findings: what do they mean, and why do they matter?

The main finding of this study is that there is a link between the awareness of students that there is a distinct mode of speech that mathematics uses and in their successful use of that mode of speech. There is not enough information or evidence in this study to suggest anything other than this link exists, but it suggests that perhaps employing teaching strategies that make mathematical language and its distinctness explicit could be productive in helping students to use it successfully. It is uncommon for even an adult learner to be aware of their own language: it is something we use almost without thinking. As such, it would seem strange to assume that students will develop this awareness on their own: and hence this study argues it should be cultivated.

This finding is primarily based on a comparison between student responses in the semi-structured interviews and on their own mathematical work. It also uses the context provided by observations of the class and the interview with their regular class teacher to gain an understanding of their prior exposure to these sorts of teaching techniques.

When composing this research, the interest was more in finding the teacher techniques that could be used to develop students' use of the register. In that regard, it was Temple and Doerr (2012) that provided the biggest motivators for the design of the study and in the classroom approaches used. As it was, however, this study has not found anything particularly conclusive or interesting in this regard. There is not enough data, nor any solid themes emerging from it, to confirm or contradict the ideas that Temple and Doerr (2012) set out. Their framework of techniques was useful, but ultimately it is hard to say whether or not it helped. Partially I attribute this to my own relative inexperience teaching: during the lessons in which I hoped to get more solid data on using these techniques, more elementary issues like behaviour management of the class meant I lost sight of these on occasion. It could be said, then, that a teacher should take care to build up their fundamental skills before attempting to layer on these more complex techniques.

Considerations resulting from Huang et al. (2005)

The prior study, which this one has ended up supporting and drawing its ideas from the most in its conclusions, has been Huang et al. (2005). They found that “student talk reflected lower-level knowledge structures, even in the presence of teacher’s discourse that illustrated varied, higher-level knowledge structures” (Huang et al., 2005, p. 48). For context: in my study, what has been referred to as ‘more sophisticated use of the register’ is close to what they meant by “higher-level knowledge structures” (Huang et al., 2005, p. 48). In other words, what Huang et al. (2005) found was analogous to the findings of this study; that it is not sufficient for a teacher to just demonstrate and use higher-level mathematical talk – it does not automatically transfer to the class. In this study, our finding has been that even if students are constantly exposed to an environment where they are asked to reason and explain mathematics, they will not necessarily notice that there is anything particularly special about this.

If they do notice, they might associate this as specifically just a mode of speech particular to the teacher. R expressed this: “how [the teacher] says something might be the same as how he talks normally: it might just be different from what I’d say” (Student R, face-to-face interview). Student J, in his discussion of how teachers talk and how teachers want you to talk, used an affected, more RP accent to signify “talking in a teacher-esque way” (Student J, face-to-face interview); this is a hard notion to communicate in text – it was a very particular ‘singsong, mocking’ voice that was recognisable in intent but does not translate to the page. This is a particular interesting strand of thought to support our finding that it is better to make more explicit the purpose of particular language usage.

What this perhaps suggests (and it really must be stressed that this is only a suggestion, and something that could be investigated with further, focused research) is that an approach towards improving students’ register use which is presented as a way of improving their way of talking towards a more technical mode of speech runs the risk of coming across, to the student, as the teacher trying to ‘make the child talk more like a teacher’. In this model of thinking, talking mathematically becomes a thing that students are aware of, but resent because they do not see it as having a true point. As such, it seems more like a hurdle that a teacher is making them pass, for reasons known only to the teacher. Notable also was the way T referred to the way of speaking in

English as “normal English” (Student T, face-to-face interview). This supports the idea that, if students do perceive the different nature of mathematical talk, they could perceive it as abnormal.

What does this imply for the development of the register? If we take it as a given (which research and the wider literature supports, as discussed in the review) that development of the register is a positive, then our teaching should address this directly. Huang et al. (2005) conclude that teachers should not just do maths but also talk math, to model for students the way they should talk. What this study suggests is that while this socialisation is important, part of it should be about convincing students that the structure and nature of mathematical talk is not arbitrary. There are reasons for the ways in which mathematics is structured and communicated in the way that it is – but it would seem, for the students in this study at least, that these are not clear. It may not be enough to communicate that talking mathematically is important: the ‘why of talk’ is important too: else the register risks being confused with a technical jargon, as opposed to the rich mode of speech that it is.

The above paragraph is quite a strong statement, and as such it really needs to be instantly suffixed with caveats. This study is very limited in scope: we are talking about conclusions drawn from a few students in one class in one school, and they are necessarily very limited. Perhaps these students’ experiences are atypical of the wider class, or represent their feeling the particular day of interview. One could not, and should not, strongly argue that the claims of this study are true based on this study alone. The limited time and scope of the study do not allow for it. What this study has done, then, is open up avenues for new investigation in this matter. In seeking to find the best ways of developing the mathematical register in students, we have found that a key part of this may be addressing their pre-existing conceptions towards the idea of it: or helping to form productive conceptions if they do not already exist.

Conclusion

In carrying out this study, I have found my ideas on the notion of the mathematical register develop and change. As a mathematician myself, and one for as long as I can remember, I had not really considered the idea that students might not recognise a difference between how we talk in mathematics versus how we talk in a normal conversation. This, however, was one of the first things I really found to be very true during data collection. It is why the focus turned more towards

students' ideas of the register, as I realised that without an understanding of that I would not be able to address the question of how to help them to learn to use it.

First and foremost, in my own teaching I am resolved to be more clear and explicit about why I ask students to speak in particular ways, or use certain terms. I want to move their perception away from seeing a jargon imposed upon them, and towards seeing it as helping them actively get better at mathematics via changing how they communicate it.

One thing I asked student D during his interview was if he ever talked about mathematics “to himself” (Interviewer, face-to-face interview). At the time I think he (and I) thought of this as an off-hand comment, and I’m not sure I meant much by it at the time. My thoughts on this keep returning to it, though. Perhaps one route towards convincing students of the relevance of clear mathematics communication is to help them develop that inner voice that helps one structure ideas. Often (as L remarked in her interview, as something that she encounters) students seem to understand ideas in some intuitive sense but do not have the words to express it: it may be that helping students understand that this aiding expression is exactly the point of mathematical modes of speech is productive for their learning.

These are my own ideas and reflections based on the issues I have uncovered for myself in this study, but I do not think they are the only possible ones that could arise. I would like to do further research – perhaps now in a more action research mode – on these specific issues – and, before that, listen to the thoughts and responses of others when presented with this study’s findings. It is through a synthesis of ideas that one can reach understanding.

If there is one thing to take away from this text, it is this: student attitudes and conceptions towards the mathematical register, whatever they are – and in this study I think we have seen only a small sample of what they might be – are crucial towards developing this understanding within them. I argue that by considering these in the planning stages, the overall quality of their learning of the use of the register could be improved.

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