How does the use of structured discussion in mathematics change the students' experience of A level mathematics?

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This paper sets out to explore the changes in students' experience through the use of structured discussion in mathematics. Previous research has emphasised the importance of talk as a pivotal factor in the richness of the student learning experience but often there is a lack of opportunity for this to take place, particularly at A level. I look at the issues of creating an environment to catalyse dialogic teaching and describe my methodology, asserting throughout that this is a simple and effective way of promoting a move towards dialogic pedagogy in day to day teaching practice for all teachers. The student response to this initiative is considered, comparing it to more traditional forms of teaching and this intervention is recommended as a valuable, straightforward, teaching tool for discursive learning.

Keywords: Dialogic teaching; collaboration; discursive learning

Introduction

Mathematics is a subject born out of discussion and argument, with its roots in philosophy. It was Hippasus who challenged Pythagoras on whether the square root of two (the answer to Pythagoras' own theorem of the length of a diagonal of a square of side one) was rational; and he was drowned…or so the legend goes. This idea of conflict, from which consensus can arise, can be lost on students today as they see mathematics presented to them and feel that it has therefore 'always been around' rather than the fact that over time, it is the best of the ideas in mathematics, the ones that have been argued over and are found to work and that can be proved, which we end up using.

My teaching takes place in a Further Education college that has a reputation for success in the high stakes world of A level examinations, with students who are generally, highly motivated and of whom, a high proportion will go on to Higher Education. The majority of the teaching is of a 'teacher-centred', 'chalk and talk' style and although this method can be effective in producing excellent exam results at one end of the scale, we also have a large proportion of students who fail the exam: twenty-two percent compared to seventeen percent nationally in 2017. Moreover, I suspect that the students have not developed 'relational understanding… knowing both what to do and why' just an "instrumental understanding…described in the past as 'rules without reasons'" (Skemp, 1976 p.2).

Consequently, I wanted to look at how to encourage more collaborative learning in my mathematics lessons and the impact of a dialogic pedagogy on the students' perceptions of how they learn mathematics, between both students and myself and the students themselves. My next question was how to achieve this.

Classroom discourse and how to support it

Over recent years there has been a growing interest in classroom discourse, as Alexander elaborates

> … the past three decades have undoubtedly witnessed a growing belief both that the quality of classroom talk is profoundly important and that its character and context need somehow to be transformed (Alexander, 2004 p.17).

Consequently, there are many 'off the shelf' problem solving classroom tasks as packages that teachers can use to promote collaborative learning, but their prescriptiveness can be a barrier to time-stretched teachers, (myself included) and each new topic would need another package to purchase or time invested in making one of your own. This argument is supported by Mueller and Fleming (2001 p.260) who assert that 'prominent writings on co-operative learning are long on prescription… but generally short on description.'

I knew of the use of individual whiteboards in primary education and then heard of wall whiteboards being used in post-16 education maths classes. Unfortunately, whiteboards fixed around the walls of our college's classrooms would be difficult due to lack of wall space and the problem of mathematics being seen by our managers as a subject that does not need a specific permanent room, meaning that the maths staff are timetabled around the college in any spare rooms that are available. As we do not teach in the same room all the time and often have zero turnaround time between lessons, it had to be a solution which was mobile, quick and easy to use. I found rolls of whiteboard sheets to be ideal: twenty-five sheet rolls of A1 size, white, cling film like material which stuck to most surfaces and were relatively cheap to purchase. This meant that I could have students in some of my classes use the whiteboards on the walls to work on mathematical problems instead of at their desks. They worked standing up at the walls on these problems in groups of two mostly, three or four at most. I told them to either copy down their work after they had completed it on the whiteboard or take a photograph if they felt they needed to refer back to their methods and answers at a later date. After establishing this activity with my classes, I asked three other mathematics lecturers (out of the eight in the team) to use the activity with GCSE as well as A level groups. One of the three used the activity with two different AS groups, so there were now four more classes able to give feedback.

To obtain the research data, for my groups, I undertook a participant observer, observational study using two of the classes that I teach as my sample; one AS Mathematics (starting the new specifications) and one A2 (Further Mathematics). By selecting one class from each year I would be able to see any differences between them. The AS group was chosen as an opportunistic sample as it was the only one taught entirely by myself. The A2 group was a similar, convenience sample as I wanted to use a group that I had previously taught, as I felt they would be more likely to be responsive and participate due to the relationships that we had already formed. I communicated my ethics protocol to the students, stressing that they were able to withdraw at any stage, pointing out that they would be video recorded but that all recordings would be anonymised. I informed them that they would be asked for feedback and possibly interviewed as well as making them aware of the focus of the research, i.e. examining the mathematics discussion in the classroom and that the findings would be shared with them. The classroom discourse was examined through recordings, questionnaires, interviews and my own reflective diary and the talk analysed through the lens of Alexander (2004) and his work on 'dialogic teaching'.

This means using talk most effectively for carrying out teaching and learning. It involves ongoing talk between teacher and students and supports students' engagement with their developing ideas and helps them overcome misunderstandings.

All students (who agreed to take part in the research) were recorded on at least one occasion when working together at the boards and they were asked to complete a questionnaire commenting on their enjoyment of the activity and how this approach compared to other lessons they have experienced. In both my AS and A2 groups, I chose a pair of students to interview in more depth. My colleagues mirrored my approach with the portable whiteboards but chose the tasks, group size and timings for the activity, themselves. Moreover, I kept a reflective diary throughout the process where I recorded my responses and reflections (usually after the lessons) and also kept notes of conversations with my colleagues about their teaching styles, and, for those lecturers involved, their responses to the research with their own classes.

Context

We are now in the first year of the new A level specifications with the WJEC (Welsh Joint Education Committee), having just had a revision of GCSE (General Certificate of Secondary Education) mathematics with the introduction of two papers, namely GCSE Mathematics and GCSE Mathematics (Numeracy), the latter having an emphasis on problem solving and application of mathematics.

In A level, the students will be examined at the end of their AS year, though these examinations only make up forty percent of the A level rather than fifty percent as was the case before. The WAG (Welsh Assembly Government) has also made the decision that the WJEC is the only examination board that can be accessed in Wales and we have been prepared for a more 'demanding' A level, where the students will be increasingly required to develop their mathematical thinking and the students will need to be more 'mathematically resilient', described here by Johnston-Wilder and Lee (2010 p.1). 'Mathematical resilience describes that quality by which some learners approach mathematics with confidence, persistence and a willingness to discuss, reflect and research.'

I am hopeful that over the next few years, as students and teachers adapt to the demands of the new Numeracy GCSE and become better prepared for it, there will be a positive impact of students' perceptions of and performance in the new examination. This should have a constructive effect on their mastery of mathematic and contribute similarly to their future studies in A level mathematics. It is within this context that I hoped to support collaborative learning as an integral part of developing the 'mathematical resilience' of our A level students.

Findings

Over the two terms when using the whiteboards in my lessons, I noted in my reflective journal that the noise levels were much higher and the students more animated. When on their feet, they were happy to cross the room to talk to other students, an activity that usually doesn't occur when they are seated. Was this change of behaviour because they are standing instead of sitting? Also evident was the ease with which I could see every group's progress at a glance, meaning that I could target the groups that were lagging behind. I felt that there was a difference in the way the students were learning and was pleased to find positive questionnaire responses.

The 'open' questions inviting comments are more problematic to analyse unless there is a method of reducing them (Cohen, Manion and Morrison, 2000). I

used a classification of coding by Hoon, Oliver, Szpakowska, and Newton (2014). It is a system '…which assessed firstly whether the response was positive (P), negative (N), adequate (A) …then looking at the depth of feedback, for P/N/A responses, as descriptive (1), qualified (2) or constructive (3), (Hoon et al. 2014 p.4).

The results are tabled in fig. 1 below:

Fig. 1

Feedback Response Code	Number AS (percentage in brackets)		Number A2 (percentage in brackets)	
P1	0	(0)	0	(0)
P2	10	(77)	7	(58.3)
P3	1	(8)	0	(0)
N1	0	(0)	0	(0)
N2	0	(0)	1	(8.3)
N3	0	(0)	0	(0)
A1	0	(0)	0	(0)
A2	2	(15)	4	(33.3)
A3	0	(0)	0	(0)
Total	13	(100)	12	(100)

For both year 12 and 13 the majority of feedback was either 'positive' or 'adequate' but then my subjective judgement could be biased.

Teacher learning

Mason (2000 p.97) makes the hypothesis for tertiary education 'that the style and nature of questions encountered by students strongly influences the sense that they make of the subject matter'. He also argues that the teacher should show their inner incantations', 'A tutor can carry out standard techniques in public (on a board or at an overhead projector), while at the same time exposing some inner incantations:

> 'I always start with the inside bit … then I take this over here … now what do I want?... Well, I know that … so … and so on.'
>
> 'At the very least it awakens some students to the fact that one might have an inner dialogue while performing a technique.' and 'It provides…an opportunity to see an expert make mistakes, check their work, and expose their inner incantations.' (Mason, 2000 p.97)

My personal inner incantations are evident in my A level teaching and I am more than happy to show them. I was hoping to hear something similar from the students when they were recorded at the boards. I was not disappointed, as this extract from a student interview shows, when they refer to both their inner dialogue and mine:

> '...so I look at the question and I say "So, *XXX*… dy/dx blah blah blah", so I do it as I'm talking … sort of like you do as you're teaching, kind of as I'm writing it I'm talking it through, like almost to myself and to *XXX*. It helps me work as well. Like even when I'm doing it normally, when we're doing individual work, I kind of say it to myself as well. It helps me run through things.'

There can still be anxiety at the start, as one A2 student comments, about the idea of working with someone he did not know so well.

> 'I think, first of all, you are a bit anxious, a bit slow to get going. You don't really want to suggest anything … to sound arrogant … 'cos you're afraid you might be wrong … be embarrassed "oh, what do you think of me now !" But, I think over

> time, when you've had the first one [correct] and you've got a successful answer, your confidence grows …'

In helping each other reach common understandings, another advantage of the activity is the ease to both self-check answers just by looking at nearby groups and also to ask someone else, even on the other side of the room, how they solved the problem. This is not an action that would happen if they were sitting down.

Impact on teachers' practice

In my reflective journal after the first sessions I raised some questions that I hoped to answer: What is the optimum size of group to work together in this way? How often should you use the activity and can it be used for general practice of mathematics, investigative and summative tasks?

The activity needs a 'just right' task level of difficulty to create the ideal situation for exploratory talk to flourish. Having tried to analyse why it needs this 'just right' task, on reflection, I think it is the magnification and exposure of what is happening in the classroom when students are standing up working at the walls. There are, I am sure, many lessons that have taken place over the years which I have failed to pitch right, but the reaction has not been so marked. If the work was too easy or not enough, the students tended to keep quiet about it; and if too difficult; they gave up and chatted. However, when standing around the room, their presence and reactions seem more intense.

As for group size, I feel that pairs of students work best, though some of my colleagues found groups of four worked well. An obvious advantage of the activity is the ability to see the students' methods at a glance, meaning that I can talk to them about other ways of proceeding; this is difficult when they work at their desks as I cannot necessarily see what they are doing unless I deliberately make a point of looking over their shoulder or ask to see their progress.

Impact on others

My colleagues, who used this activity, all had some initial reservations and they were also starting to use it during revision time with the students, having finished the course for both GCSE and A level. However, this worked out well, as the whiteboards lend themselves to revision tasks. Despite initial worries and overcoming organisational difficulties, all three colleagues had a similar positive reaction from their students. The questionnaire responses for the four groups together, with 27% and 40% responding in codes P1 and P2 respectively and 23% and 10% responding in codes A1 and A2 respectively.

Here are some of my colleagues' observations:

- Class enthusiastic and happy to have a go.
- Pupils discussing how to answer, helping each other with lots of mathematical discussion throughout.
- Good for teacher as able to help and point out mistakes easily as could see quickly
- Students happy to call you over if needed help. Able to write on board to help them and they could scrub out / finish off themselves.
- As working in groups students have confidence to try questions. They were able to prompt each other if they had forgotten things.
- Some groups took turns, others nominated a scribe.

- Worked well for revision lesson – students confident enough to write up answers for all to see.
- Useful tool to assess problem areas and help address these.
- Feedback to each group immediate so they were able to learn from their mistakes.

Their observations echo mine.

Concluding comments

Next academic year I will use the boards with more classes and so will some of my colleagues, as our college is investing in some permanent whiteboards to have around the classrooms and I have presented CPD (Continuous Professional Development) to colleagues who teach GCSE and A level mathematics. The use of the whiteboards and the subsequent discourse this activity creates is, in my opinion, a more effective way to teach; resulting in an improvement in my understanding of pedagogy especially dialogic teaching. The activity is an accessible, simple and cost-effective way of creating a 'community of enquiry' which can support students to make connections and meaning; a learning endeavour that promotes students' 'exploratory talk' and helps them focus on 'working on understanding'.

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