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Teachers' Accounts of Developing Mathematical Resilience in the Classroom

Clare Lee and Robert Ward-Penny

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1. Introduction

This paper reports on a professional development programme in mathematical resilience, and the experiences of the teachers taking part. The programme introduced the teachers to the construct of mathematical resilience, and explained how it was relevant and valuable to the teaching and learning of mathematics. The participating teachers were encouraged to apply the principles of mathematical resilience, and to reflect on their actions through conducting a small-scale action research project in their own school environment. What follows in this paper are examples of how mathematical resilience was deployed in these schools, alongside some examples of the changes reported by the teachers in their own practice and that of their students.

2. Background: The Schools

The data was collected as part of a co-operative venture between one of the authors and a mathematics hub funded by the NCETM. The mathematics hub wanted a continuing professional development (CPD) course for their teachers, and felt that the researcher's work in the area of mathematical resilience was of interest. The mathematical resilience CPD project was offered to all of the schools served by the mathematics hub, and twelve schools chose to attend: six secondary schools, four primary schools, and two schools that worked with secondary aged students who had behavioural difficulties.

At the first meeting the ideas and principles of mathematical resilience were outlined and the participants were given time to discuss the concept and ask questions. The researcher explained what it meant to conduct a small-scale action research project and allowed the teachers time to confer and come up with an initial idea for a project they felt they could pursue in their own classrooms. At the second and third meetings the teachers began by reporting on what they had done in their schools in the gaps between meetings. They then discussed any issues that were encountered and how best to overcome them, and talked together about mathematical resilience. In each of these meetings the researcher worked firstly to keep time, so that everyone had an opportunity to talk about their own project, and secondly to make notes, dually for research purposes and for summarising events for the mathematics hub. Although the researcher answered direct questions, the participants steered the meeting and were the primary influencers.

The fourth meeting was different in that the teachers were to use this time to write a report on their project. At the start of the meeting the group discussed how such a report might be written and what might be included. Each pair was asked to write a quick summary of their project, and then after 20 minutes the teachers swapped computers, so that they could read one another's reports and question each other on what had been written. The participants were then given the remaining meeting time and another two weeks to edit and submit their reports.

The schools in the group each approached the ideas of mathematical resilience in different ways. Two pen portraits are offered here by way of example.

One pair of teachers from a primary school who taught in year 2 and year 5 decided that the way that they classified their students according to a measure of attainment prevented many of their students developing mathematical resilience. They stopped allotting different seats where the students had to sit for mathematics and allowed them to sit in their normal classroom places. They reported that making this small change made the ethos of their classrooms feel quite different. Previously the children seemed to have expected only one table of students, where the higher attaining children sat, to volunteer answers to any questions posed by the teacher. After the change, the teachers observed that answers were coming from everywhere in the room. The teachers particularly noticed that students who had previously sat quietly were now answering questions. They reported that all of the students were now taking part in the lessons rather than many sitting back and letting the "clever" ones answer. There was also a greater recognition of different learning preferences in the classroom, such that the children were expected to choose from three or four different ways to learn more about a given topic, sometimes in consultation with the teacher. The teachers reported that they wanted to emphasise that it is the students' responsibility to learn and the teachers' role to facilitate that learning. The classroom became an inclusive community of those who wanted to and were enabled to learn mathematics.

The teachers from one secondary school decided to respond by using contexts that were of interest or familiar to their students, in order to generate interest and engagement and to begin to uncover the mathematics that is used in the world. They used several ideas to draw attention to the relevance to the mathematics that they were covering in the curriculum. In one lesson the teachers began by showing a video of an English astronaut who was in the International Space Station at the time, and then they asked the students to generate mathematical questions about the situation. At first the students were slow to ask questions, but gradually and collaboratively the students posed questions about space and the space station. Each question was recorded faithfully and neither judged nor re-worded; the teacher's intention was to include the students in the community of those that can pose mathematical questions and to value with the students' contributions. When the teachers judged that the flow of questions was diminishing they asked the students to look at all the questions and pick out the ones that they felt to be worth working on. A list of questions was

generated and the students used the mathematics they already knew to provide answers. They explored ideas and made connections, challenging themselves in ways that the teacher did not expect. Working in this way meant that the students began not only to uncover the extent of mathematics that is present in the world but also to see that they can engage with mathematics themselves and find solutions. The teachers went on to offer a similar way of working using other stimuli, for example a piece of bubble wrap, each of which extended the students' thinking and ability to connect aspects of mathematics.

3. Limiting Factors

Most of the schools reported successful implementation of many of the principles of mathematical resilience. Only one school was completely unable to implement the ideas. However, there were clear limiting factors to the extent that some schools could make use of the ideas that were discussed in the meetings. In the most pronounced cases, there were two primary schools where the teachers who were most enthusiastic about the project moved to another school, and the way that their roles were covered meant each school was unable to continue to be involved. Another two teachers were very enthusiastic at first, but they found that opposition by their senior leaders to any changes in the way that mathematics lessons were conducted precluded continued involvement with the group.

Teachers from one secondary school took part in every meeting but the last and were clearly developing the ideas in their school context. However no written report was received from this school as staffing changes meant that the two teachers who were part of the project were left as the only teachers in their department who had higher mathematics qualifications. They had to focus their efforts on inducting the teachers who would be teaching mathematics for the first time in the following academic year and helping them plan effective lessons.

4. Aspects of Mathematical Resilience that are Readily Assumed into Teachers' Practice

The data in the reports readily suggests that many aspects of mathematical resilience can be developed usefully and with benefit to students in both primary and secondary schools. These are listed in the table below and then discussed in turn.

	Aspects of Mathematical Resilience that are readily assumed into teachers' practice are:
1.	an emphasis on the growth mindset and working to counter the fixed mindset.
2.	learning tasks that show mathematics has value within the real world.
3.	an overt and conscious inclusion of all learners in a community of those learning mathematics.
4.	enabling students to learn the vocabulary of the mathematics community so that they can take part in mathematical discourse.
5.	showing learners that learning mathematics involves "struggle" whilst ensuring that they have ready access to support, thereby guarding against anxiety being established.
6.	making sure that learners know how and when to seek help, and how to give help.

Growth is important

One of the key aspects of working for mathematical resilience seen in the teachers' accounts was that of developing a growth theory of learning (Dweck, 2000). A minimum response seems to have been displaying posters that encouraged the use of language that emphasised that the ability to engage with mathematics can be grown. For example one school put up posters with the slogan "don't say I can't do it – say I can't do it YET!" Those teachers who really began to encourage their students to think in growth terms about learning mathematics found that they had to involve the whole school. They discovered that when their students left their classrooms other staff members were speaking in ways that encouraged their students to think that only some people were able to do mathematics, or which implied that students must find ways to 'just remember' processes as it was impossible for most people to understand and connect mathematical ideas. These participants held meetings of the whole staff in order to explain the ideas of the growth mindset. In these meetings they stressed the importance of encouraging the students to see that making the effort to understand would help their brains to grow more connections and to become able to understand even more (Boaler 2016). They felt that all staff in the school needed to express the idea that there is no limit to the mathematics that students can understand and use given the right support and effort.

Teachers from multiple schools looked at the systems that they used in their schools and saw that they were labelling students and emphasising that more was expected from some learners than from others. They felt that the previously unquestioned systems of dividing up students into sets or into "tables" meant that their students were inclined to develop a fixed mindset. Several schools changed the way that they asked their students to sit within the classes. Instead of sitting students by 'ability group' they introduced the idea that all students were expected to understand and use each aspect of mathematics that was studied, although due to differences in previous experiences individuals would need different support. They offered a variety of ways to work on each area of mathematics but allowed each child to make the decision for themselves about how much support they needed and how they wanted to learn. One teacher reported that when looking back on her previous practice she wondered why she had felt she could make a decision about the support a student needed without reference to that student. Offering choice and support in making good decisions about the way to learn mathematics seemed to be a natural consequence of thinking about developing mathematical resilience.

Showing that mathematics has value within the real world

Those teachers who were working at secondary level (ages 11-19 years) felt that considering the personal value of mathematics for the students was important in developing mathematical resilience. Although this was less of a priority in the primary schools, participants from all of the schools considered that they needed to work differently so that

their students ceased to view mathematics as a bundle of disjoint procedures to remember, but instead saw it as an exploration and connection of ideas.

Inclusion in a community of those learning mathematics

The idea of inclusion within a community of learners featured in most of the schools' reports. It was typically expressed through the principle of enabling the students to make their own choices in how they supported their learning, rather than via the actual content that was to be learned. The teachers acknowledged that some students were better than others in making these choices and saw part of their role as helping the students to be able to assess where to start and what their learning goal might be. For example in one school the teacher offered several choices of ways to approach the mathematics learning, one of which was to work on a table where the teacher was working. However she stipulated that the students had to have a good reason to work on this table, and that "not knowing your seven times table was not a good enough reason!"

Learning the vocabulary of the mathematics community

This was a further feature of a classroom developing mathematical resilience. Helping the students to use the vocabulary and ways of expression that are a necessary part of using and reasoning with mathematical concepts (Sfard, 2008) was regarded as important by the teachers across the age range. One teacher who worked with secondary age students discovered that one of his students, who was aged 16 years, had never been helped to understand what may be considered very basic mathematical vocabulary and thus felt completely excluded from any discussions, causing him to withdraw himself rather than appear ignorant. Understanding and using the vocabulary of mathematics is a vital part of feeling included in the community of those who engage with and use mathematical ideas (Lee, 2006). Making sure that the language of mathematics is being used by the students, and not just the teacher, is an important part of developing mathematical resilience.

Learning that mathematics involves "struggle"

The teachers related different ways in which they helped their students come to understand that learning to use and control mathematical ideas involves a certain amount of struggle. Research has previously suggested that many teachers and students see struggle predominantly in a negative light. For example, Stigler and Hiebert (1999) have identified that many teachers in the USA see their job as "path-smoothing" (Wigley, 1992) when teaching mathematics and consider themselves to have failed in their teaching role if their students become "stuck" or cannot immediately identify the way forward. This attitude appears to risk creating students who consider that making mistakes or not being able to move smoothly through some mathematical problem means that they "can't do it", or that the teacher has not explained the idea well enough.

In a similar way, many of the teachers reported that their students seemed to be ashamed if they made a mistake and that mistakes were to be hidden rather than acknowledged. They were reluctant to seek support to understand why the mistake was made or what to do

about it. In order to counter these ideas the teachers explained to their classes that in order to learn mathematics they must think and reason, and further that learning may well involve making mistakes. They helped the students appreciate that learning involved some struggle and perseverance, but that they were not struggling alone, and support was readily available. One school did this by celebrating “today’s big mistake”, an activity in which they asked their students to explain where they made a mistake and what they did about it. Several teachers stressed that if the students were not making mistakes then the level of challenge they were experiencing was not high enough to enable them to learn as well as possible. They talked about moving from the students’ comfort zone into their growth zone (see Fig. 1) where they were learning something new. During lessons teachers challenged their students to move into their personal growth zone, often asking the students



Fig. 1 The growth zone model

themselves to choose work which would enable their learning to grow. Being in the growth zone is a slightly uncomfortable experience for some learners; it has an element of risk as the student is asked to do something new and different. The students were therefore offered support in terms of peer collaboration or other help including ICT as they needed it. The teachers also talked about an anxiety or “red” zone which students could move into if they took on too much, or if they did not seek appropriate support.

Students were told to acknowledge if they were entering the red zone and take steps to return to their growth zone, by changing what they were doing, seeking more support or collaborating with another student. The teachers worked to communicate the principle that learning mathematics involves some struggle but not too much.

Knowing how and when to seek help and how to give help

Collaboration between peers was considered important in the reports as the teachers saw that working together meant that the support necessary to sustain a student when in their growth zone was readily available. Collaboration in mathematical learning had to be developed in many of the schools as the teachers and students were used to a more individual approach to teaching and learning, reflecting the isolationist ideas referred to by Nardi and Steward (2003). One school had already begun to expect their students to collaborate as much in mathematics as they were already doing in all other subjects. However, they noticed that the students were less adept at “helping one another learn” in mathematics than they were in other subjects. Many children sought help too soon, or they were reluctant to “have a go” for themselves and instead wanted to work with someone they saw as more capable from the start. Rules had to be established as to what constituted “being stuck” and therefore needing help.

The students of this school also needed to explore how to give help when learning mathematics; even though the school had adopted growth mindset ideas many years

previously they found many students saw help in mathematics as “giving the right answer”. The teachers dealt with this partly by changing the tasks they used to enable their students to learn mathematical ideas. They began to use tasks which asked for explorations that could be individual to each student, and for explanations. They also presented the students with scenarios and asked them to reason about whether the help supplied in each would help learning. This enabled the students to know both when to seek help and how to give help.

5. Conclusion

As well as providing examples of mathematical resilience in action, this research project has shown that most schools are able and, perhaps just as importantly, willing to engage with the ideas that make up mathematical resilience. The teachers’ reports show that adopting these ideas in schools does make a difference to their students’ willingness to learn and to use mathematical ideas.

Each of the schools engaged in a distinct way with the principles and practices of mathematical resilience. The accounts of the teachers suggest not only that an environment that encourages the development of the characteristics of mathematical resilience can be fostered in all schools, but also hint at some of the factors which might lead to mathematical resilience growing more readily and steadily.

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