Developing mathematical resilience

Conference or Workshop Item

Developing Mathematical Resilience

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Many people find mathematical tasks difficult, to the point that they exhibit phobia or anxiety, or at least avoidance from engaging in any endeavour that could require mathematical reasoning. We have defined a construct ***mathematical resilience*** (Johnston-Wilder and Lee 2008) by which we mean a positive approach to mathematics that allows people to overcome any affective barriers presented when learning mathematics. In this paper, we discuss an action research project intended to develop the characteristics of *mathematical resilience* in pupils in one school and the ways in which using this construct can help overcome negative attitudes to mathematics and therefore aid learning.

Mathematical resilience describes that quality by which some learners approach mathematics with confidence, persistence and a willingness to discuss, reflect and research. All learning requires resilience; however, we contend that the resilience required for learning mathematics is a particular construct as a consequence of various factors including: the type of teaching often used, the nature of mathematics itself and pervasive beliefs about mathematical ability being 'fixed'.

Currently it seems that mathematical resilience develops by accident, if at all. This study is a thick description of a deliberate effort to increase the mathematical resilience of the pupils at one school. We worked with the staff in school to build a mathematically supportive community, for example we recruited mathematics coaches with no strong mathematical knowledge of their own, but with willingness to sit alongside learners and face their mathematical demons together. The learners became more aware of their own learning and better able to continue their struggle to understand and know mathematics. Further, the process of naming 'mathematical resilience' gave non-mathematics specialists access to ways of supporting the learners. The whole school were recruited to the endeavour to think and talk about mathematical learning and thereby to become a school that consciously promotes mathematical resilience in its pupils.

Key words:
Mathematical resilience, mathematical teaching and learning, mathematics anxiety, barriers to learning

Introduction

Our experience echoes the literature (e.g. Ashcraft, 2002, Baloglu,& Koçak, 2006 and Hoffman 2010) in indicating that many people find it difficult to take part in mathematical learning, to the point that they exhibit phobia or anxiety, or at least avoidance from engaging in any activity that could require mathematical reasoning. This reaction has been widely documented in the literature on mathematics anxiety (e.g. Ashcraft, 2002 and Rodarte-Luna & Sherry 2008) which shows that many people approach mathematics with some degree of fear. We have studied literature relating to recovering from adverse conditions and abuse (e.g. Borman & Overman, 2004 and Newman, 2004) and have found it helpful in coming to an understanding the source of these difficulties. In fact the more that we studied stories from people who exhibit mathematics phobia, and read the related literature, the more that it appeared to us that the way that mathematics is often taught in English mathematics classrooms is an unwitting form of cognitive abuse. Instances of ways of working that seem calculated to cause anxiety are asking learners to perform tasks that require feats of memory at a rapid rate or to memorise formulae without understanding in classrooms where the mathematics is divorced from the reality that it models so powerfully. These ways of working have been shown by many researchers (e.g. Boaler 2009, Jain & Dowson, 2009 and Baloglu & Koçak, 2006) to cause anxiety. Acting in such a way that many people are made to feel anxious, concerned or fearful seems to us to be acting in an abusive way.

However we do not want this paper to focus on negative actions or to lament over the dreadful state of mathematics teaching in England. We want to consider how teachers could act to make the classroom a more positive place to be. If mathematics is difficult to master, and we see that it often is, we want to ask how can teachers enable learners to develop a positive adaptive stance to mathematics which will allow them to continue learning despite barriers and difficulties? To this end we have defined a construct we call ***mathematical resilience*** (Johnston-Wilder and Lee 2010) by which we mean a positive affective stance to mathematics. Pupils who have mathematical resilience will persevere when faced with difficulties, will work collaboratively with their peers, will have the language skills needed to express their understandings or lack of it and will have a growth theory of learning, that is they will know that the more they work at mathematics the more successful they will be.

It follows that teachers seeking to build mathematical resilience in learners will encourage collaborative working where learners support one another in learning, use the power of assessment for learning (Black et al 2003) to enable the pupils to both understand their own rights and responsibilities in the process of learning and to support them in knowing when and where to put in their learning effort. There will not be ‘competitions’ to see who can recite memorised answers most quickly but rather activities designed to help pupils learn mathematics and also to use their mathematical understanding. In this way we are seeking to interpret Dweck’s work on mindsets (Dweck 2000) in the context of learning mathematics.

Therefore we will discuss the way that focussing on the characteristics of the construct ***mathematical resilience*** can help change mindsets and overcome current negative attitudes to mathematics. The evidence shows mathematical resilience can be developed in learners when the ethos of the school encourages people to see that learning takes effort but that that effort will result in improvement. Therefore in our study we seek to engage the whole community of the school in the quest to improve the mathemtical attainment of the school. We saw this as meaning involving all teachers of mathematics, which, of course, includes teachers in other curriculum areas and auxiliary staff such as the dinner ladies and the receptionist.

Focus of the enquiry

Having become convinced that there was value in focusing on the positive construct summarised by ‘mathematical resilience’ (Johnston-Wilder and Lee 2010) and that we could define its characteristics we looked to work with a school to increase the mathematical resilience of its pupils.

A meeting of a STEM (DfES 2006) careers project in which we are involved brought home to us that teachers in school and parents do not feel empowered to help with 'the maths problem' and that 'the system' is increasingly putting pressure on mathematics departments to enable its students to succeed at GCSE. However mathematics departments in England are typically struggling to recruit sufficient teachers and feel immense pressure to enable their school to meet externally imposed targets.

At the STEM meeting one of us talked to a chairman of the governors of a school about our ideas and she invited us into her school. Although mathematics departments have the expertise to set out the curriculum it seems to us that the whole school must take corporate responsibility for enabling its pupils to succeed in meeting targets for attainment in mathematics. Expecting a depleted mathematics department to shoulder all the responsibility seems to be ill-advised. Experience and research indicates that non-specialists have much to offer the process of developing confidence in mathematics. Also part of what is needed is a shift in focus from 'ability' to 'learning strategies' for working at mathematics, taking into account affective aspects of learning such as what mathematics looks like in the adult world of home and work, and what strategies adults have developed to cope with situations involving mathematics.

We therefore wanted to find the answers to the research question 'How can we work within schools to enable all the adults to build mathematical resilience in their learners?' The study is Action Research as we question 'how can we improve our practice when engaging with schools in advisory capacity?' The research went through cycles as we will describe in this paper. There were cycles within cycles as we sought to plan a three year intervention that would allow our professional practice to respond to the needs of the school.

We wanted to work in such a way that resilience was developed in the pupils and to enable the school to embed ways of working that would enable it to meet the challenges of its own particular context. Initially we thought that the project would involve setting up a staff briefings, letters home to parents and a series of staff and parent workshops negotiated with the school. However as we worked within the constraints of the school, what we wanted to do and what we were able to do changed in response to the needs of the school. In this paper we explain what we did in the first year of working in the school and why we chose those activities. We will present a study of a deliberate effort to increase the mathematical resilience of the pupils at one school, our successes and where we still need to develop our ideas.

We know that currently mathematical resilience is not developed purposively. This is not to say that it is not developed at all. We know many mathematics teachers who work hard in their classrooms to enable their pupils to enjoy and succeed in mathematics in ways that we know develop resilience. However currently mathematical resilience happens by accident where it happens at all. It was not hard to find ideas for developing mathematical resilience; journals aimed at mathematics teachers provide many such ideas. However all too often mathematics teachers do not use these ways of working consistently and revert to the seemingly safe, stereotypical mathematics lessons. Such lessons use a *restricted practice* of teacher exposition of a single isolated technique followed by pupil completion of exercises practising the technique, the exercises being aimed at helping pupils remember how and when to use that technique (Nardi & Steward 2003, Ofsted 2008),

We are also aware that many teachers feel that they have to restrict their practice in this way because of the amount of external assessment that is required in English Schools and the high pressures that are placed on teachers to enable their pupils to perform in these assessments. We therefore considered that if we could measure mathematical resilience and therefore measure whether it increased or not we could offer an inducement to use ways of learning that we know to be more beneficial to the student's mathematical well-being. Therefore we began work on designing a questionnaire that would measure student's resilience basing our measuring tool on adaptations of instruments that have been published (Dweck 2000 and Fenema & Sherman 1976).

The Research

Global reconnaissance

As indicated above we use the term ‘mathematical resilience’ to name that quality by which some learners approach mathematics with confidence, persistence and a willingness to discuss, reflect and research. All learning requires resilience; however we contend that the resilience required for learning mathematics (‘mathematical resilience’) is a particular construct as a consequence of various factors including: the type of teaching often used (Nardi & Steward 2003, Ofsted 2008), the nature of mathematics itself (Mason et al 1985, Jaworski 2010) and pervasive beliefs about mathematical ability being ‘fixed’(Dweck 2000, Lee 2006). Helping learners to develop mathematical resilience enables them to adapt positively to the difficulties presented by mathematics and to be in a position to consider continuing to develop their mathematics beyond compulsory age.

The current system of teaching and testing seems to develop in learners an entity or fixed theory of learning (Dweck 2000, Harlen, 2005) that makes them believe that they are either good at mathematics or they are not. Even those who see themselves as being good at mathematics when at school may not develop mathematical resilience as every time they get stuck they ask their teacher, who ‘smoothes the path’ (Wigley 1992) for them. They may not meet problems that require ‘struggle’ and therefore may not develop ways to deal with adversity.

Many learners experience the process of learning mathematics as a process of facing severe adversity; in this sense, mathematical resilience is a positive adaptation to enable success. (Newman 2004). If learners are to engage with mathematics, struggle through problems, deal with barriers and misunderstandings and work on mathematical ideas, then they need mathematical resilience. In the UK, many people become anxious about maths (Baloglu & Koçak 2006). Mathematics anxiety severely compromises the ability to carry out mathematical processes and is, for many, an acquired response to school situations rather than being innate (Ashcraft 2002). The origins of mathematics anxiety lie in part in the interactions between learner and teacher (Ashcraft, 2002).

There is also an indication in the literature on anxiety (Ashcraft 2002) that articulation of ideas improves learners’ confidence in both their learning and their competence to use mathematical concepts; that is, it increases their mathematical resilience. Speaking or otherwise communicating is an important part of developing mathematical resilience; becoming able to articulate mathematical ideas, concepts and reasoning has a profound effect on the way that learners see themselves (e.g. Lee 1998, 2006, Mercer and Littleton 2007, Vygotsky, 1981). An individual takes on the identity of a mathematician (Holland et al. 1998, Lave and Wenger, 1991, Wenger, 1999) by learning how to talk like a mathematician. Giving learners the opportunity to ‘talk like a mathematician’ means that they become someone who ‘knows and can do mathematics’; that is, they become mathematically resilient.

Local Reconnaissance

We began to work in the school in ways that we believed would increase mathematical resilience. The school we had been invited to work with was in an urban area with a high level of disadvantage experienced by the pupils. Many came from homes where unemployment was the norm and had been since the main industrial base of the area had closed. There was a diversity of cultural heritage in the school. From our perspective the main disadvantage experienced by the school was that they were unable to recruit sufficient well qualified mathematics teachers and therefore many of the pupils' experiences of mathematics was overseen by people with limited expertise in mathematics. The school's main concern was the performance of their students in the mathematics GCSE – an examination taken at age 16 in England. Data from the results of GCSE examinations in Mathematics and English plus 3 other subjects is used in England to judge how successful a school is in catering for the needs of its pupils. Low achievement in mathematics can result in punitive measures being placed on the school by government agencies, including being merged with another school. Therefore mathematics mattered to the school and the poor recruitment of mathematics teachers was a source of anxiety for the Senior Leadership Team (SLT).

Working in the School

Measuring Mathematical Resilience

The first thing we did in school was to administer a questionnaire that we had devised in order to measure mathematical resilience in the pupils in the school. We wanted to know if the pupil's resilience increased as a result of our interventions therefore we used the questionnaire appended to this paper as a baseline and re-administered the same questionnaire at the end of the academic year. We intended our interventions in the school to result in a change in the mindset of the pupils, helping them to see the merit of persistence and effort in making progress in mathematical learning. Therefore we turned first to Dweck (2000) as an initial source for the questions. We also wanted to know about the pupils' general attitude to learning but also their attitude towards mathematics in particular. Hence we also incorporated elements from an existing questionnaire (The Fennema-Sherman Mathematics Attitude Scale, Fennema & Sherman, 1976) which set out to measure students' attitudes towards mathematics.

Maths Angels

As we have said previously the school had a shortage of well-qualified mathematics teachers and placed as high value on the outcome of the pupils GCSE results. Their priority was to increase the attainment of its pupils. Therefore the school needed more people willing and able to help the pupils become confident mathematicians, but they seemed to the SLT to be impossible to find. We talked to a member of the SLT and together we decided to recruit a team of 'Maths Angels' from amongst the existing staff, including ancillary staff. The Maths Angels were to act as mathematics 'coaches'. They had no strong mathematical knowledge of their own, but willingness to sit alongside learners and face their mathematical demons together.

There was no sense that these Maths Angels had the expertise to set out the mathematics curriculum but rather they were asked to provide a listening ear for the pupils. Maths Angels would listen to the problems and ask questions such as 'how did your teacher go about solving these problems?' or 'what do your notes say?' or shall we try to look up how to do that on the internet and see if we can understand together?' We hoped that such people would change the ethos of the school from one where everyone found mathematics hard to one where everyone would bring the resilience they had used to learn their subject or their job and use it to show the pupils how to be resilient when it comes to mathematics.

The Maths Angels' role was to:

- encourage pupils to talk
- encourage growth mindset attitude (Dweck 2000)

- encourage pupils to collaborate
- encourage pupils to explore internet for help in understanding mathematics concepts
- encourage pupils to experiment with ICT tools.

We held a meeting in the school of people willing to become Maths Angels and we discussed how we could support them in what we saw as a very important role. We carefully outlined that they were not required to provide ‘the answers’ but rather to support the students in finding their own. Many of the Maths Angels expressed the opinion that they had no vision of how they could help the students. Talking about mathematics appeared to be difficult for them to do.

We offered to hold supportive meetings for the Maths Angels. A meeting was held and just four people attended out of a total of about 15 initial volunteers. During this meeting one of the ‘Angels’ became so agitated by the mathematics that they were working on, that the meeting had to be stopped. Further meetings seemed inappropriate as what the school needed, they said, was for us to model different ways of working with the students.

Reflection on our work with Maths Angels

Most of the Maths Angels felt that the role we asked of them was very difficult. They felt overwhelmed by feelings of inadequacy and helplessness in the face of the students’ difficulties in mathematics. This part of our work had reached an impasse, the feelings of anxiety and fear that we knew to be widespread were so embedded in the staff with whom we worked in school that they seemed to be unable to help the students because of their own feelings of anxiety.

As the school had asked us to model different ways of working with students in mathematics we reflected how we could respond and settled on holding extra-curricular classes on preparing resiliently for mathematics GCSE papers with pupils from Years 10 and 11 and working with mathematics videos with Year 9. We chose these particular ways of working with the school as we felt that they would enable us to model the ways of working that we had asked the Maths Angels to use. The school was a specialist ICT college and therefore making videos would allow us to make use of existing strengths as well as requiring the students to practice behaving resiliently.

Further work in the school

We planned two different ways to model ways of working to increase mathematical resilience. Firstly we planned two sessions that would show the Year 10 and 11 examination classes resilient ways to respond to studying for their GCSE examinations. The school very much appreciated these sessions as their focus was clearly on improving their students’ mathematical attainment at GCSE. Secondly we planned to work with a Year 9 class to make videos explaining certain mathemtical ideas that they had recently been considering in their normal mathematics classes.

Making videos

The literature, for example Sfard, (2008) and Lee (2006), indicates that pupils must articulate their mathematical ideas in order to effectively learn mathematics. It seems that placing pupils in the position of having to communicate what they are learning is at the core of increasing both the pupils’ resilience and their thinking and learning. Sfard (2008) is clear that learning and communicating are intricately intertwined. The current mathematical culture in the school was resistant to pupil articulation with a heavy emphasis on teacher exposition and little opportunity for pupils to express their emergent understanding or misunderstandings.

After consideration, we chose to use the medium of short videos to prompt pupils to articulate their ideas. We asked a class of Year 9 pupils, aged 13 and 14 years, to collaborate in making their own videos to explain some mathematical ideas that they had recently been working on. Socio-cultural theorists (e.g. Vygotsky 1981) suggest that pupils learn from working collaboratively to build knowledge. Asking the pupils to make a video provided clear roles for each member of the group and we believed would provide motivation for the pupils to articulate their explanations in a clear and concise way.

In total the pupils produced seven videos about their understanding of aspects of the mathematical concept of transformations. These videos were included in an MTi article (Lee and Johnston-Wilder, 2010) Each group of four pupils was given an aspect of transformations to work on for example: reflection, what is the same about reflection and rotation, what is different about reflection and rotation, how enlargement differs from the other transformations. Each group was asked to plan their video, devise any resources they wanted to use and script the voiceover. The task was designed to stimulate discussion within the groups about the concepts as the pupils worked on how to explain their ideas using mathematical language. As we observed the pupils planning and storyboarding their videos we saw the kinds of discussion that we had planned for. The pupils asked one another: what shall we say? how can we show this idea as well as that? The task seemed sufficiently important to them to engage and motivate each pupil. One group taught themselves the idea of negative enlargement in order to extend their video presentation.

About a week after we had worked with the pupils to make the videos we returned to the school with the edited videos and showed them to the pupils. We then interviewed the students in order to gain their perspective on the value or otherwise in engaging in tasks such as the one we had asked them to do.

The pupils' evaluations.
The pupils' responses showed that they appreciated that this way of working was different from their usual way of working in mathematics lessons; they said that *"we could work as teams instead of doing work all by ourselves."* The pupils believed that they achieved more because of the energy they able to expend appropriately when working in this way. They described having to *"double check that we'd got it right, in what we were doing for the video"*, and said that "*teaching ourselves stuff, it made it easier in some ways".* They knew that collaborative working helped them; one girl said: *"you can talk to other people while you're doing it and like, ask them questions and things like that*", and another commented, *"yeah, you can ask for help and other people can, like if you're stuck on something, they can show you how to do it".*

The pupils were convinced that they learned more because they worked collaboratively; they said, for example, "*with teachers, people normally just say oh yeah I understand that, but with your friends you'll just say if you don't understand it,"* and *"with your friends… if you don't understand it you can keep asking them 'til you definitely know you know how to do it."* They also commented on the importance of being allowed to be independent: "*you can like get on with your own work and… figure it out for yourself. So you're not bored".*

They contrasted working in this way with their usual normal activities in mathematics lessons: *"I liked how we were all active … it's better than just sitting around doing maths work"*. Apparently their usual maths lessons were *"boring like normal lessons when you just like sit there doing sums"*. Their experience of mathematics lessons is no different from many English schools (Nardi & Steward 2003) especially those that are short of qualified mathematics teachers. The widespread belief that 'good' or ‘effective’ mathematics teaching is the teacher explaining and the pupils doing exercises on their own is often hard to overcome. However, it is a belief the pupils in this school would like to challenge; their comments reinforce the need for change:

“G1: I think we actually learned more doing the videos cause we actually wanted to do it, and in normal maths lessons it’s just a bit boring so we don’t really want to learn”
“G2: we’re not having to sit there and listen to someone explain something. We’re doing it ourselves, and we’re learning from our own abilities.”
“G3: we’re still learning it, but more enjoying it as well.”
“G4: but if we’re actually up and active then we’ve got the energy to do something, but it still sort of processes more”[1]

The boys also welcomed the opportunity to articulate their mathematical ideas and seemed to understand that this would be important in making the concepts they were dealing with memorable and taking ownership of those ideas.

“B1: I think just because like you’re normally just sat there doing like in a book you just write down and you don’t really say anything, when you’ve actually got to say, you’ve got to think about what you’re saying.
B2: In the book work, you write, you write down the sum, you’ve done it, you don’t go back to it, whereas we made the script several times, over and over again. So you learn them, you have to learn the lines.

There were several aspects to the video activity which the pupils seem to have recognised as good learning opportunities. For example, the scripting of the video was important:

“G1: Yeah. I don’t think I knew as much about rotation before, now I do,
R: so how do you think that works, then? You’ve been making a video, not learning maths.
G1: yeah, I think it’s cause we actually have to write out what we were saying, so we have to go through it in our own mind, what we were actually going to say and then we get it, like, yeah.’

The act of videoing required the pupils to practice using the ideas that they had met before and they ‘*learned it better’*. They were prepared and motivated to repeat actions and think ideas through until they had thoroughly explored the ideas and could articulate them, because the outcome would make the record of their understanding more permanent.

“G1: I think that we kind of learnt something new, but like we knew about it already, like, rotation, reflection
G2: we learned it better
G3: we learned, we already knew two things, like we were doing rotation, we knew reflection, but we learned how they were the same, and how they linked in with each other.”

“G4: I don’t think I knew, like, how many times like the shapes go into each other, when pulled, but I do know that now.

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[1] In this and subsequent excerpts from our data G means a girl, B a boy and R is the researcher. Where the letter is followed by a number it is there to distinguish between speakers in a given excerpt. G1 is not the same speaker in successive excerpts.

R: and do you feel you know that confidently now?
G4: yeah. Cause we did like so many different ones, so many different pictures."
"G5: cause you actually have to come up with the question, you're having to think about it in more detail."

The making of the videos was successful in motivating these pupils to reflect on, think through and practice their understanding of transformations. They said that it helped them to feel confident in their knowledge and therefore to increase their willingness to recall and use ideas about transformations. Producing a video was important; as one girl said, "*instead of reading stuff it's actually watching it which is more interesting, really. Kind of grabs your attention more*."

The nature of the task required the students to engage with challenging ideas, they could have produced a video on rotation that just showed something rotating but they were not prepared to do that. They also worked collaboratively; and it is clear from their evaluations of the experience that collaboration was important in helping these pupils to learn effectively and efficiently.

"G1: It helped us understand as well, cause like if we don't understand it, then we'll be like watching all the other groups show us how to.
R: …So if you didn't understand your topic, the others helped you?
G1: Yeah, in our group.
R: …. So did you have conversations where you were helping each other?
G2: Yeah, and cause they're like, they're all our friends and that, they help us to understand it cause it's in like our own language as well."

The pupils' comments lead us to believe that what worked about the task to make a video was:

- there was an end product that pupils were committed to producing
- pupils had independence as to how they went about the task
- pupils had a group focus on a challenging task
- the pupils worked collaboratively (Swan 2006) they did not just work in a group
- the pupils were active and these active pupils harnessed their energies constructively
- the pupils had to articulate their ideas clearly;
- in clarifying the scripts for the videos, the pupils saw the learning happening for themselves
- because the pupils were focusing on the video, repetition and consolidation of the ideas came naturally.

Of course, we cannot say that the pupils have become more mathematically resilient from just this one activity; however, the pupils told us that they enjoyed working in this way and that the focus and motivation to understand made them more confident in their understanding of transformations. Mathematical resilience is about that confidence in what is understood and knowledge about what to do if you do not understand. We can say that the pupils' confidence increased and that they could articulate how they increased their confidence in their understanding. They also told us that they felt supported in answering a challenging task and knew what to do to overcome any barriers that they encountered. Therefore we believe we have taken a step towards increasing these pupils' mathematical resilience.

We will leave the last words to the pupils:

"G1: Should probably just say, like it's a good way to get the kids involved and interested in what you're trying to teach them"

"G2: It was really enjoyable, and memorable"

"B: Well, we won't forget it, that's for sure."

Quantitative Outcomes

The GCSE results in the summer of 2010 were 47% A*-C which showed a marked increase from last year's results of 35%. Of course this cannot be directly attributed to any of our interventions as these results are the culmination of many actions by the school but we are told by the deputy head that our work in the school contributed greatly to the school's feeling that they could achieve the results that they needed.

Discussion

We found that by naming and defining the construct of 'mathematical resilience' the school had something that they could discuss and decide how they could develop. Previously the school's target was to improve their examination results which can seem a nebulous target, improving the pupils' mathemtical resilience seemed in contrast more concrete. They could increase the students' willingness to take part in discussion of mathemtical ideas by using certain activities in their next mathematics lessons. We therefore continue to argue that mathemtical resilience is an important construct and that teachers and policy makers can be enabled to develop it and to measure how successful they have been in enabling their learners to become mathematically resilient.

Further, the process of naming 'mathematical resilience' gave non-mathematics specialists access to ways of supporting the learners. This was perhaps the least successful part of our work in the school as we underestimated the level of support that the teachers and support staff would need in order to overcome their own anxieties and be in a position to help students. We will continue this work next year with fewer volunteers and much more support.

The tools we used to measure mathematical resilience showed that the learners became more aware of their own learning and better able to continue the struggle to understand and know mathematics. However the tool is not sufficiently discriminatory as it stands. Although the pupils were in general more positive about their mathematics learning and seemed to have greater understanding that they would improve their learning by their own efforts we cannot say if that is because they generally feel more positively disposed towards school in the summer than in the autumn. We need to explore a measuring tool in much greater depth before we are ready to offer it to a wider public.

The videos were successful in asking the pupils to articulate their understanding, work collaboratively and be persistent. However there are many other ways that students can be asked to engage in these activities that we know develop resilience towards mathematics and the pupils were wise enough to tell us that although they enjoyed making the videos they wanted such lessons to be one of a variety of activities that required them to think and act mathematically.

Conclusion and what next?

We have illustrated how the use of a positive construct "mathematical resilience" can contribute to improving mathematical culture in a school struggling to recruit a full complement of mathematics teachers. The school continues to experience difficulty in recruiting experienced mathematics teachers. The Head of Department has now left the school and there is now a vacancy in the school for which they have recruited someone to start in January. The school has also recruited two new members of staff, one experienced and one newly qualified. Therefore we will have to renegotiate our interventions in the two subsequent years to take account of the strengths of these new personnel.

As we consider our own practice we know that we need to continue to work on the ideas around ‘Maths Angels’. The data that we have gathered on the use of ‘Maths Angels’ illustrates how the mathematical ethos of a school is affected by what we see as a national pandemic of mathematical phobia and anxiety and a strongly embedded fixed mindset in mathematics. Our study shows how difficult it is to overcome these features of the way that people approach mathematics even in people who have volunteered to be part of this project. We have asked ourselves whether it is appropriate to expend our energies on working with adults and whether their attitudes are so deeply ingrained they cannot be changed. However we always come back to if the students are surrounded by adults who are convinced that mathematical learning is something to be anxious about and is different from other learning then how can they develop resilient attitudes to mathematics? Also the mathematics results of the school must be seen as a corporate responsibility, a few teachers cannot shoulder the whole burden in the current assessment climate. Therefore we must continue to work in this area.

We will also continue to work at developing a measuring tool for mathematical resilience and this will be our focus this year. The current tool is not sufficiently discriminating to show progress in developing resilience year on year therefore we will work with statisticians this year to modify and improve our existing tool.

However our work with Years 10 and 11 and the videoing project show us that using different ways of working is highly effective in enabling pupils to understand that they can both learn mathematics and use that learning in different ways. The latest data that we have from the school is that they have 47% of their pupils achieving a grade of A* - C in mathematics this year compared with 35% last year. This is impressive and shows how well the school has worked with its pupils, we are happy that we were able to make a contribution to supporting them in this improvement.

We have endeavoured to provide a thick description of a journey towards involving the whole school in ‘the mathematics problem’ over one academic year – the journey continues.

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Thinking about Learning

We want to know what you think about learning in general and learning mathematics in particular. Please answer all the questions as honestly as you can, there are no right or wrong answers.

Please state what year you are in _

Please state whether you are a girl or a boy _

Questions about how you think about intelligence and learning in all your lessons

1. Think about ***all*** your experiences in school and answer this question

Tick the sentence that is most true for you

___ when I get new work in school, I'm usually sure that I will be able to learn it.

___ when I get new work in school, I often think I may not be able to learn it

Now show how true the statement is for you – indicate with an 'X' on the line

very true for me	true for me	sort of true for me

Read each sentence below and then circle the **one** number that shows how much you agree with it. Remember there are no right or wrong answers.

2. If I knew that I wasn't going to do well at a task I probably wouldn't do it even if I might learn from it.

1 strongly agree	2 agree	3 mostly agree	4 mostly disagree	5 disagree	6 strongly disagree

3. Although I hate to admit it I sometimes would rather get good marks than learn a lot.

1 strongly agree	2 agree	3 mostly agree	4 mostly disagree	5 disagree	6 strongly disagree

4. You can learn new things but you can't really change your basic intelligence

1 strongly agree	2 agree	3 mostly agree	4 mostly disagree	5 disagree	6 strongly disagree

5. If I had to choose between getting a good mark and being challenged in class I would choose … (Please circle one)

"good mark" "being challenged"

Thinking about how you learn in Maths

5. Tick the sentence that is most true for you

___ when I get new work in mathematics, I'm usually sure that I will be able to learn it.

___ when I get new work in mathematics, I often think I may not be able to learn it

Now show how true the statement is for you – indicate with an 'X' on the line

very true for me	true for me	sort of true for me

6. I can get smarter at maths if I work hard – please circle one

1 strongly agree	2 agree	3 mostly agree	4 mostly disagree	5 disagree	6 strongly disagree

Beliefs about learning mathematics

✓ Tick the sentence for each belief that reflects how you think – ***you can tick as many as you like*** - there are no right or wrong answers

Belief 1: About solving time-consuming mathematics problems- please choose one.

Maths problems that take a long time do not bother me.	
I feel I can do maths problems that take a long time to complete.	
I find I can do hard maths problems if I just persevere.	
If I cannot do a maths problem in a few minutes, I probably cannot do it at all.	
If I cannot solve a maths problem quickly, I stop trying.	
I am not very good at solving mathematics problems that take a while to figure out	

Belief 2: About understanding in maths - please choose one.

Time used to investigate why a solution to a maths problem works, is time well spent.	
A person who does not understand why an answer to a maths problem is correct, has not really grasped the problem.	
In addition to getting a right answer in maths, it is important to understand why the answer is correct.	
It is not important to understand why a mathematical procedure works as long as it gives the right answer.	
Getting a right answer in mathematics is more important than understanding why the answer works.	
It does not really matter if you understand a mathematics problem if you can get the right answer	

Belief 3: About how useful maths is - please choose one.

I study maths because I know how useful it is	
Knowing maths will help me earn a living	
Maths is a worthwhile and necessary subject	
Maths will not be useful to me in my life's work	
Maths is of no relevance to my life	
Studying maths is a waste of time	