UNIVERSITY OF CAMBRIDGE
Faculty of Education

*ISSN 2043-8338*

*Journal of Trainee Teacher Education Research*

# Exploring teaching strategies to promote mathematical resilience in a Year 10 set 4 mathematics class

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## Abstract

*Many students experience the phenomenon of mathematical anxiety when approaching mathematics inside and outside the classroom. Literature suggests that mathematical anxiety may be reduced through the development of mathematical resilience. However, few studies have considered how to develop such a characteristic. This piece of action research suggests that mathematical resilience can be developed through the introduction of teaching strategies which encourage student discussion and collaborative work. Several strategies were introduced and evaluated whilst teaching a middle-set Year 10 mathematics class at an all-girls school. This study has shown that mini whiteboard work, question tickets, matching activities and confidence-building starters are particularly useful tools. The success of such teaching strategies being applied elsewhere will rely upon the presence of a positive learning environment as well as the regular recognition of what it means to be mathematically resilient.*



https://doi.org/10.17863/CAM.83620

# Exploring teaching strategies to promote mathematical resilience in a Year 10 set 4 mathematics class

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## Introduction

Whilst teaching mathematics at my second Postgraduate Certificate in Education (PGCE) placement school, I noticed a distinct lack of confidence towards independent work by students in several classes. This was particularly evident in a Year 10 middle-set class. At a similar time to when I arrived at this school, the mathematics department introduced a new classroom routine where students were to complete a minimum of ten minutes of independent work in each mathematics lesson. I was surprised by how difficult this seemed to be for both students and teachers. Students frequently asked for help and their teachers were constantly moving between desks trying to answer queries. This highlighted a severe lack of confidence in students to approach mathematics alone and resulted in increased stress for both students and teachers.

Through discussion with my mentor, I considered how to develop the mathematical resilience of the Year 10 middle-set class. It was an opportunity to research the topic of mathematical resilience and consider how this may be developed in students through teaching strategies and wider classroom pedagogy. This was an action research project where teaching strategies were introduced in order to improve students' mathematical resilience. Discussion activities, pair-work and mini-whiteboard work were introduced and evaluated across five lessons on the topic of inequalities. Students' mathematical resilience was described in lesson observation notes which were then analysed for common themes such as lack of resilience, development of resilience and evidence of resilience.

Johnston-Wilder and Lee (2010a) describe how many mathematics lessons consist of "a teacher exposition of a single isolated technique followed by pupil completion of exercises practising the technique" (p.5). This has resulted from pressure placed on teachers regarding pupil performance. However, this seems to be causing the issue of mathematical anxiety and is detrimental to students' mathematical learning identity (Darragh, 2013; Johnston-Wilder & Lee, 2010a). Literature suggests that mathematical anxiety can be negated through the development of mathematical resilience.

In this paper, I give an overview of literature regarding mathematical resilience, reference mathematical anxiety and discuss teaching strategies which have been found to improve student resilience. I present data to suggest that mathematical resilience can be developed through teaching strategies which promote student discussion, collaboration and positive learning identities. This contrasts from teaching styles traditionally associated with the mathematics classroom.

## Literature Review

### Mathematical anxiety

The phenomenon of 'mathematical anxiety' is well documented in literature. For many, the idea or action of learning mathematics leads to anxiety or a phobia - even when outside the mathematics classroom (Johnston-Wilder & Lee, 2010a). This 'acquired' response of anxiety has compromised the ability of many to think mathematically or complete mathematical tasks (ibid.). Thus, mathematical anxiety may be considered a contributing factor to the avoidance of mathematics and mathematical careers. This may explain why only 7 per cent of British students choose to study mathematics in post-16 education (Cropp, 2017). It is unlikely that all those students who do not study mathematics in post-16 education experience mathematical anxiety. In contrast to other countries, mathematics is not a compulsory subject in post-16 education in the United Kingdom. As a result, students may simply choose to study other subjects. Unfortunately, some students will decide to avoid mathematics due to mathematical anxiety.

It is believed that traditional assessment and teaching strategies are partly responsible for 'maths anxiety' (Johnston-Wilder & Lee, 2010a). Field (2018) relates mathematical anxiety to the negative or 'fixed' learner identities which are common in mathematics classrooms and states that this has led to the belief that "failure is viewed as the reflection of intelligence" (p.30).

I have heard countless students exclaim that they will "never be good at maths" and that they often feel "lost" while attempting to do mathematics. This has been echoed by parents when they have shared their own perceptions and experiences of the subject at parent-teacher evenings. It is important therefore that classroom teaching and activities are adapted so that students have a positive and rewarding experience of mathematics. Educators should consider the suggestion of

Johnston-Wilder and Lee (2010a) and others that mathematical anxiety can be reduced through the development of mathematical resilience.

## Mathematical resilience

Johnston-Wilder and Lee (2010a) define mathematical resilience as “that quality by which some students approach mathematics with confidence in a successful outcome to their effortful work, persistence in the face of difficulty and willingness to discuss, reflect and research” (p.1). Johnston-Wilder and Lee (2010b) also helpfully outline how mathematical resilience relates to a wider definition of resilience that links to physical and psychological resilience. Unless otherwise specified the term ‘resilience’ is being used in relation to ‘mathematical resilience’ throughout this paper.

It is important that mathematical resilience is investigated, as it has previously been assumed that mathematical resilience “develops by accident, if at all” (Johnston-Wilder & Lee, 2010a, p.1.). They contend that “mathematical resilience is a consequence of factors such as the type of teaching used, the nature of mathematics itself and pervasive beliefs about mathematical ability being ‘fixed’” (ibid.). More research is now considering how to develop resilience through various teaching strategies. They outline that teachers should focus on teaching and learning strategies in mathematic classrooms, rather than focusing on ability. Through the promotion of resilience, positive change in the learner identities of students may be encouraged. This follows the finding of Boaler, Wiliam and Zevenbergen (2000) that contrasting pedagogies lead to different mathematical identities – in both a positive and negative way. A positive change to a student’s learning identity could be a transition from a fixed theory of learning to that of a growth theory of learning (Johnston-Wilder & Lee, 2010a).

Darragh (2013) has shown that positive mathematical learner identities are vital as students make the transition from primary school to secondary school. Holding a constructionist view of learning, Darragh states that when feelings of belonging are fostered in the mathematics classroom, confidence and positive mathematical identities are promoted. This contrasts with a typical fixed mindset where confidence flows from a previous belief of being mathematical. Darragh (2013) claims that “in the mathematics classroom students learn more than just mathematics; they learn what it is like to be a member of a mathematics community, and whether they want to be a member of this community” (p.216). Boaler et al. (2000) outline that “the kinds of strategies adopted by teachers in the face of a student's 'failure to belong' would be very different from those suggested by a 'failure of ability'" (p.11).

As a result, a teacher's role is to foster a positive learning environment where students can construct a confident mathematical identity and feel a sense of belonging. This requires communication and depends upon successful relationships between students and between students and their teacher. Darragh hopes that this will challenge an assumption that confidence is equivalent to competence in the mathematics classroom. The promotion of positive learner identities would help more students to continue with mathematical studies (Boaler et al., 2000): "Through studying how students learn about mathematics, they also learn how to make sense of learning mathematics and sense of themselves." (p.4).

There are few studies which have explored this construction of mathematical identities. Consequently, Boaler et al.'s (2000) contributions to this area of research are significant. They carried out 120 interviews with secondary school students of mathematics across England and the United States. This contrasts to Darragh's study (2013) which was carried out as a case-study where six students were interviewed once. It is significant that these studies are complementary, despite their different research methods.

**Literature on strategies to promote resilience**

Previous literature regarding mathematical resilience highlights common values. Johnston-Wilder and Lee (2010a) outline the importance of articulating and discussing mathematics, stating that "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" (p.5).

Whilst it is important to note the importance of articulating mathematics, the above quote from Johnston-Wilder and Lee (2010a) necessitates an important distinction between confidence and competence. Care must be taken to distinguish confidence from competence (Darragh, 2013). In the mathematics classroom, it has been expected that confidence results from competence, however this follows the common belief of mathematical ability being 'fixed', as outlined by Johnston-Wilder and Lee (2010a). It is this 'reverse' situation of confidence leading to competence (Darragh, 2013) that I sought to encourage with the Year 10 class.

Field (2018), Cropp (2017) and Boaler et. al (2000) highlight the importance of giving students the opportunity to speak and discuss mathematics. Field (2018) carried out an action research study where six students were evaluated on their resilience in a problem-solving task. Negative body language and failure language showed a lack of confidence for students when they were unsure of their answers. Two students tended to doubt their answers "in order to 'hedge their bets' and be right either way" (p.30). Cropp (2017) found that peer mentoring can be used to help build mathematical resilience and thus reduce mathematical anxiety. In this study, mentors modelled to their peers how to 'cope with being stuck' and provided encouragement to those struggling with mathematical anxiety. According to Cropp, peer-mentoring provides a valuable and key opportunity for dialogue between students which can be difficult to facilitate as a teacher.

It is also possible to build resilience through collaborative work. Johnston-Wilder and Lee (2010a) found that students developed their mathematical resilience through the opportunity to work collaboratively on an explanatory video project. This is linked to the socio-cultural theories of Vygotsky, who contended that individuals learn from one another. This contrasts to a 'typical' classroom situation of students doing exercises on their own (ibid.).

Turner (2018) investigated the use of 'wrong' answers in further education to encourage engineering students to generate a more confident approach to their subject. It was stipulated that this approach requires a very positive learning environment in order to work effectively and so would not be appropriate with a group lacking confidence. Foster (2016) and Baker (2019) both set out to increase mathematical resilience through the adoption of confidence assessments. Foster introduced confidence assessments and 'negative' marking to class assessments across four teaching sessions. Students were asked to give a confidence mark between zero and ten for each answer, where if they are incorrect then they lose that number of marks from their total. Negative marking aimed to discourage students from guessing. Foster (2016) suggests that these methods seem "to provide a way of rewarding and encouraging realistic self-confidence in mathematics" (p.13) whilst informing teachers and helping students to become more self-aware.

Whilst confidence and resilience may be closely linked, there is an important difference between the two. It can be detrimental for students to be overly confident, however students can never be 'too resilient.' Field (2018) explains that "when students have been overconfident and proved incorrect, they are in a worse position than if they had been a little less sure of themselves at the outset" (p.30).

As Field points out, over-confidence can be as detrimental as under-confidence. Thus, the use of confidence assessments over time as outlined by Foster (2016) could be an effective way to self-correct students' confidence. Baker (2019) also introduced confidence assessments alongside low-stakes quizzes. This was found to be a useful tool for formative assessment as well as a valuable opportunity to experience test-conditions without additional anxiety. Both studies found that the use of confidence assessments helped students to become more self-aware and identify areas which they were struggling with, and thus target these in their independent work.

Despite a wealth of literature promoting pupil discussion, the reality of mathematics teaching practice does not prioritise these values. The typical practice of mathematics teaching was summed up well by a pupil interviewed by Boaler et al. (2000):

> "We go to class and the teachers lecture, go over the material and show us exactly how to do the problems, cover the subjects that they are teaching and after the teacher's finished teaching we ask questions and sort of like clear up anything we don't know…"
>
> (Boaler et al., 2000, p.6)

Despite their best intentions, teachers may too often "revert to the seemingly safe, stereotypical mathematics lessons" (Johnston-Wilder & Lee, 2010a, p.5). This could be a result of the pressure facing teachers to fulfil assessment requirements and the pressure for their students to perform well.

Johnston-Wilder and Lee (ibid.) have carried out several research studies in order to address this issue and provide practical suggestions to help educators. In 2010, they carried out an action research project seeking to develop students' mathematical resilience, and so aid learning and overcome negative attitudes to the subject. From this research project, they state they importance of adopting a whole school approach to promote mathematical resilience where a definition of mathematical resilience is shared and promoted across all school areas. Furthermore, they share how it is important that teachers and students share the same definition of resilience.

Overall, literature suggests that mathematical resilience is a vital characteristic for students to develop. The studies above attest that mathematical resilience can be promoted through regular mathematical discussion, collaborative working, peer-mentoring, confidence assessments and regular conversation around what it means to be resilient and a learner of mathematics. With consideration to this literature, two research questions are explored in this piece of action research:

**RQ1:** What does mathematical resilience look like in the classroom?

**RQ2:** How can mathematical resilience be promoted or improved in the classroom?

An overview of the research design and methods implemented in this study is given before considering these research questions.

## Research Design and Methods

### Action Research

Cohen, Manion and Morrison (2017) define action research as "a small-scale intervention in the functioning of the real world and a close examination of the effects of such an intervention" (p.226).

With the intention of improving student mathematical resilience, this research has been carried out as an action research study. This was appropriate as I did not set out to solely explore the topic of mathematical resilience, but to improve this characteristic in a class of Year 10 students through my own actions. I considered Cohen et al.'s (2017) example of improving student attitudes and values through the introduction of teaching methods. They describe this action as "replacing a traditional method [of teaching] by a discovery method" (p.441).

A strength of action research is that it can improve best practice for the teacher carrying out the research, provided it has been successful. Admittedly, the evidence produced by action research is not held to such scrutiny as that desired in other academic research. Nevertheless, this experiential approach can present evidence which is 'good-enough' to inform our immediate classroom practice (Taber, 2013). On the other hand, academic research can claim to be generally applicable by obtaining abstracted theoretical knowledge (ibid., p.149). Action research may be considered less rigorous, because it "is likely to cut short any intervention that does not seem to be having the desired effect" (ibid., p.144). This follows from its nature as classroom-based research designed to improve practice.

As previously mentioned, there has been interesting research into the development of mathematical resilience. This has not led to substantial change in classroom pedagogy. As action research helps to bridge the gap between research and practice (Cohen et al., 2017), it is an appropriate research tool to bring about informed change. In this study, I used an adaptation of Taber's (2013, p.144) action research cycle as shown in Figure 1.

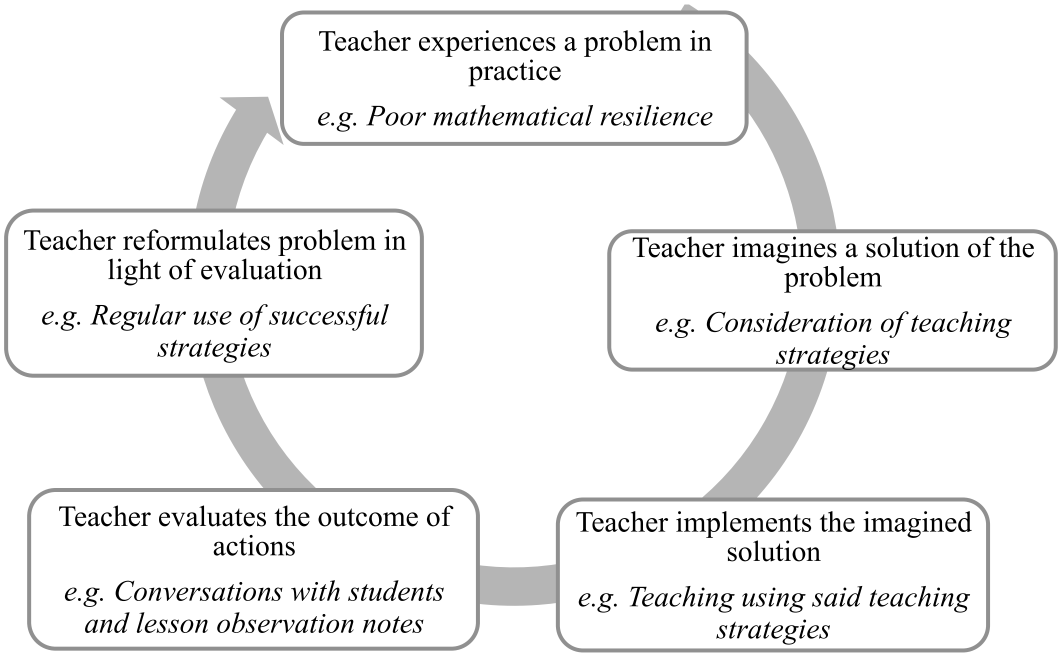


**Figure 1: Action research cycle** (adapted from Taber, 2013, p.144)

A potential limitation to action research is its highly contextualised nature (Taber, 2013). As a result, it can be very difficult or inappropriate to generalise findings or use it to inform other practitioners. For example, this study was carried out in a single class in a single school. Furthermore, the school is a single-gender school. Consequently, it is unrealistic that this class is considered representative for their age-group or attainment set (ibid.). This raises queries as to whether it is wise to apply the findings of this research to other contexts.

It is important that action research in its "complex and multifaceted nature" (Cohen et al., 2017, p.441) is distinguished from the everyday actions of teachers. Action research, when effective, presents opportunity for review and action. It is essentially collaborative and more personal for participants compared to the work of external researchers (Cohen et al, 2017). It is important to recognise that "many of the positive outcomes could relate to the special activities devised for the group or the full-time presence of a teacher or the value of group work itself" (Taber, 2013, p.182). This is an anticipated limitation of action research. It can, however, be negated through carrying out several 'cycles' of action research. The teacher should observe their class on several occasions and through various contexts and so attempt to distinguish 'normal' behaviour from that arising from action research. Due to my limited timescale, it was not possible to carry out extended cycles of activity and evaluation as recommended by Taber (2013). However, this issue has been helped by the fact that I had been observing and teaching this class for almost a full term before this lesson sequence. I would recommend that future studies employ a greater timescale to strengthen the reliability of their findings.

Whilst carrying out a small-scale investigation, research techniques should be used which are not "too minimal to be valid" nor "too elaborate to be feasible" (Cohen et al., 2017, p.455). This highlights the difficulties which can arise when seeking to compare and generalise findings between contexts. Action research can sometimes be viewed as "more descriptive of the reflective process than being evaluative or emancipatory" (ibid.). When reporting action research, questions may arise regarding the validity of findings. For this reason, it is key that the success criteria used to evaluate the action research is justified (Cohen et al, 2017).

Darragh (2013) also carried out an action research study at an all-girls school in a middle-set attainment group. This research contributed to knowledge regarding the development of and importance of mathematical identities. Darragh highlights how her personal experiences of teaching and learning mathematics have impacted her action research. She shares her perspective of learning mathematics as a female from an ethnic minority group. This has given her sensitivity to the feeling of not belonging in mathematics and influences her interpretations and conclusions of her study. In contrast to my placement school, students involved in Darragh's study had diverse ethnic backgrounds. She carried out semi-structured interviews with six students. She then carried out thematic analysis on these responses to identify and construct themes. A limitation of Darragh's research is that she asked for interview volunteers. These six students were the first to volunteer and discuss their mathematical identity and experiences of learning mathematics. Consequently, they may be more likely to have a positive mathematical identity than those students who did not volunteer.

**Justification of research techniques**

There were 33 students in this Year 10 class at an all-girls school. When this class reaches Year 11, some students will sit the General Certificate of Secondary Education (GCSE) Higher mathematics qualification whilst others will sit GCSE foundation mathematics. This class was a suitable group of students for this action research study for several reasons. Of all the classes I taught at my placement school, I had the greatest familiarity and experience with this group. Before I began teaching them, I was able to observe my mentor teach this class and thus observe their lack of mathematical resilience. They struggled to carry out silent independent work, often desiring to check their answers with their neighbour, myself or my mentor. Through discussion with my mentor, I decided to carry out action research to build the mathematical resilience of these students.

I planned to carry out a group interview before and after teaching the lesson sequence. However, it was only possible to carry out a group interview before the lesson sequence due to the national (Covid-19 pandemic) health crisis. This group interview was carried out with four students prior to teaching the research lessons. From this, I gathered student opinions on resilience and what it means to be confident in mathematics. These students were asked to participate as I believe they represent the general confidence levels of the class well. In lessons, these individuals often seek affirmation or support with their work from myself or those around them.

Throughout a sequence of five lessons, my mentor took detailed lesson observation notes regarding pupil behaviour in relation to resilience. She recorded reactions of the whole class and did not specifically observe those involved in the group interview. Lesson observation (LO) notes and group interview notes have been used as raw data to answer each research question in turn. As well as presenting the findings of each research question, I discuss the significance of these in relation to previous literature. As previously explained, I was not able to gather student opinions in a second group interview. This would have presented a valuable opportunity to discuss each teaching strategy and provide evidence to answer my research questions. However, as the students were aware of the purpose of my study, they may have been reluctant to make 'negative' comments (Johnston-Wilder & Lee, 2010a). I instead evaluated the resilience of the whole class in order to strengthen the viability of my data.

Lesson observation notes were analysed for common themes, as modelled by Darragh (2013). I recognised three themes relevant to mathematical resilience; lack of resilience, development of resilience and evidence of resilience. The first theme, the 'lack of resilience', has been analysed and discussed in consideration of research question one. The remaining themes of the 'development of resilience' and 'evidence of resilience' have been considered in line with research question two. The content of the lesson observation notes would have been influenced by my mentor's previous experience and knowledge of these students. Similarly, my interpretation of lesson observation notes and evaluation of lessons will have been influenced and informed by my own experiences of this class as a trainee teacher.

**Ethical considerations**

As with any research method, there are ethical challenges to be aware of whilst carrying out action research (Cohen et al., 2017). This research has followed the current guidelines on educational research ethics issued by the British Educational Research Association (BERA) (2018). These guidelines have informed the research methods used and my actions as a teacher in a position of care for students. In line with appropriate confidentiality and anonymity guidelines, names of the school and students have been anonymised.

I received permission from my mentor and professional tutor to carry out this research in line with this school's policies and procedures. I obtained voluntary informed consent by those interviewed. Participants were reminded that they were free to withdraw at any point and that their responses would remain confidential and would not affect any assessment or report or lead to detrimental consequences in any way (Taber, 2013). The remaining students were not aware of any reason behind my use of teaching strategies, unless they spoke to the four students who were interviewed.

My school mentor and I discussed whether it was necessary to seek explicit permission from the class for this action research. As these teaching strategies would be considered part of normal, good teaching (Taber, 2013), it was concluded that specific permission was not necessary. This helped prevent student behaviour being influenced. My mentor did, however, continue to act as a 'gate-keeper' for the class throughout this research and so held power to refuse permission at any moment (ibid.). In addition, as classroom teacher, she also ensured that the lesson sequence closely followed the department's scheme of work.

**Outline of lesson sequence**

Once it was decided that the Year 10 class would be a suitable choice for this research study, I consulted the mathematics department scheme of work in order to plan an appropriate topic. The topic of inequalities was selected as it was due to be taught soon and could be completed in a manageable number of lessons. It was important that these teaching strategies were implemented in a new topic. I planned to employ at least one teaching strategy in each lesson, however it was possible to use more than one in some lessons. The lesson sequence, taught between 11th and 18th March 2020, and the teaching strategies used are shown in Table 1 below.

| **Lesson no. & Topic** | **Teaching Strategy** |
|---|---|
| **Lesson 1** (L1)**:** Introduction to inequality signs | Whiteboard work<br>Discussion time in pairs |
| **Lesson 2** (L2): Solve single variable inequalities and represent on a number line | Confidence boosting starter<br>Addressing misconceptions<br>Students writing answers on the board |
| **Lesson 3** (L3): Solve two linear inequalities | Question tickets |
| **Lesson 4** (L4): Shading regions given by inequalities 1 | Matching activity<br>ICT Tools - GeoGebra |
| **Lesson 5** (L5): Shading regions given by inequalities 2 and recap of topic | Whiteboard work<br>Confidence ratings |

**Table 1: Teaching strategies employed to teach topic of inequalities**

## Findings and discussion

As previously discussed, lesson observation notes and group interview notes have been used as data to answer two research questions. Three themes were evident in lesson observation notes with respect to mathematical resilience. Students showed a ‘lack of resilience’, ‘growth in resilience’ and ‘evidence of resilience’. The theme of a ‘lack of resilience’ will be discussed in consideration of research question one. The remaining themes of ‘development of resilience’ and ‘evidence of resilience’ will then be discussed with respect to research question two. As well as presenting these results, I discuss their significance in relation to relevant literature.

## Research question 1: What does mathematical resilience look like in the classroom?

Data from the group interview was considered to answer this research question. Four students were involved in this group interview in advance of the lesson sequence. When asked what it meant to be resilient at their school, one student answered that being resilient meant to "work through things and gain confidence". The word 'resilient' is promoted as one of six values upheld by the school, and so it was interesting to hear student opinion on this. It has been shown that students and teachers should have a shared understanding and definition of what it means to be mathematically resilient (Johnston-Wilder & Lee, 2010a). Whilst it was possible to hear one student's opinion on this, the other three students were unsure of what it meant to be resilient. As a result, I would suggest that my placement school should clarify not only what resilience is as a general value, but also how resilience can be shown in different subjects, such as mathematics.

To "work through things and gain confidence" links to Johnston-Wilder and Lee's (2010a) definition of mathematical resilience as "that quality by which some students' approach mathematics with confidence in a successful outcome to their effortful work, persistence in the face of difficulty and willingness to discuss, reflect and research" (p.1).

### Lack of resilience

The theme of 'lack of resilience' was evident in lesson observation notes, especially in the introduction lesson to the new topic of inequalities. This was highlighted when the class used mini whiteboards in lesson one:

> *"You can see their dependence on each other…by the fact that they keep comparing answers"* *(LO, L1)*

The teacher went on to explain that though *"they look confident"* doing whiteboard work *"they do still compare with the person next to them a lot!"* (LO, L1). Mini whiteboards are a quick and useful way to test pupil understanding, however students may sometimes feel anxious to be seen giving an incorrect answer. This is evident in the above observation notes and is supported by my experience as their teacher. Many students did not want to display their answer until most of their peers had already shown theirs. I sought to overcome this by asking them to reveal their answers after a countdown. It is also worth noting that the successful use of mini whiteboards, as with other strategies, depends on a positive learning environment (Turner, 2018).

This class have used mini whiteboards frequently in mathematics and even other subjects. As a result, their dependence in lesson one highlights the nerves or uncertainty they may feel when first introduced to a new topic. Ideally students would not feel nervous for being uncertain in a new topic. I would hope that they would not feel judgment for making errors in a new area of mathematics, but rather demonstrate a growth-mindset (Johnston-Wilder & Lee, 2010a). The success of using mini whiteboards is not measured by how many students show the correct answer, but how many students are answering honestly, and so can receive help when needed.

A lack of resilience was also noted in lesson two:

> *"They do get 'flappier' when [solving linear inequalities] is introduced and more obviously vocal about it being harder. I've heard some say things like 'this is so confusing' and 'I'm so lost!'"* *(LO, L2)*

Several students voiced negative emotions and confusion at this point in the lesson, as evident in these quotes. It is encouraging that these students felt able to communicate how they were feeling and reach out for support. However, this highlights a lack of resilience as these students were struggling to "persist in the face of difficulty" (Johnston-Wilder & Lee, 2010a, p.1). I desire for students to develop a growth mindset where they show willingness and desire to overcome such difficulties. This will be discussed further later in reference to my second research question.

Whilst the use of mini whiteboards initially highlighted a lack of mathematical resilience, they were also shown to bring about positive development of resilience towards the end of the lesson sequence. The below observation helps indicate how this class can demonstrate resilience. This will be discussed in more depth with relation to research question two.

> *"It's funny how they work really quietly and independently when they are doing well with a topic – you can see they are enjoying their work – well done for creating such a purposeful environment."* *(LO, L2)*

**Research question 2: How can mathematical resilience be promoted or improved in the classroom?**

I sought to promote mathematical resilience using teaching strategies such as the use of mini whiteboards, discussion activities and confidence building starters. In order to answer this second research question, each teaching strategy was evaluated using evidence from lesson observation notes, starting with the use of mini whiteboards.

**Use of mini whiteboards**

Although mini whiteboards initially highlighted pupil uncertainty and dependence, they were also found to be a successful tool for improving mathematical resilience. It was found that mini whiteboards help students *"to have a go even when they aren't sure"* and help them stay "*engaged and participating*" (LO, L1). Immediately after the use of mini whiteboards, students worked well in some independent work, as shown in the following quote:

> *"They all work really well on the board questions. Not many ask questions at all, which is unusual! They appear to be confident with what you've done so far." (LO, L1)*

In lesson five, there was further evidence to suggest that mini whiteboards were an effective tool:

> *"Lots and lots of mini whiteboard work to start. It appears to be working well as a way to recap all their inequalities skills and a way for you to see what areas still need work. When I'm watching students work, I can see them using the boards to rub things out and then try different ideas. I can also hear [two students] discussing if it is $\frac{1}{3}$ or $\frac{3}{1}$ so it's nice that they can reach an agreement and then rub things out!" (LO, L5)*

Mini whiteboards provide an opportunity to practise many questions quickly. This can help to address misconceptions quickly and so promote understanding in a topic. However as outlined by a student in the group interview, mini whiteboard activities do not leave evidence or working to use for revision afterwards. As a result, students should also have enough notes in their workbook to look back upon for revision or consolidation.

Whilst I was teaching, it was possible to adapt questions according to how the class was doing. This form of assessment for learning was complemented with the use of a confidence vote. When students were asked to rate their confidence on a one to five scale, most gave a score of four (LO, L5). I believe this was an accurate representation, as each mini whiteboard also provided an additional opportunity for me to assess pupil understanding.

Confidence ratings have been very helpful in my teaching as an assessment for learning technique. However, there are other benefits to gathering students' confidence ratings. As mentioned previously, Foster (2016) and Baker (2019) used more formal 'confidence assessments' in their research. These studies showed that confidence assessments when used with negative marking systems help students to become more self-aware and help identify areas for independent study. I believe that it would be beneficial to incorporate more formal confidence assessments into my teaching. This would provide an opportunity to regularly discuss pupil confidence, and thus advise students on how they can become more mathematically resilient. Additionally, this could help students to take ownership of developing their resilience.

**Discussion work**

The lesson observation above (LO, L5) highlights how mini whiteboards can also lead to student discussion. As mentioned previously, student discussion is an essential activity in the mathematics classroom (Field, 2018; Cropp, 2017; Boaler et al., 2000). Discussion activities provide an opportunity for students to articulate their mathematical thoughts – a necessary step in the process of effectively learning mathematics and developing mathematical resilience (Johnson-Wilder & Lee, 2010a). I sought to increase student discussion through the use of question tickets and a matching activity carried out in pairs. Working with one another necessitates dialogue between students (Cropp, 2017) where students are encouraged to support one another in their learning (Johnston-Wilder & Lee, 2010a). By promoting student discussion, I sought to promote the development of mathematical resilience. An overview of the success of these strategies follows below.

**Question tickets**

In lesson three, students were required to work in pairs whilst working on a sheet of questions. Each pair were given three 'question tickets' which they could use at any point. When they wanted to ask a question, they traded in one of their question tickets. I noticed that the class listened very well to the instructions of the task, as they did not want to waste any of their question tickets. As they wanted to 'save' their question tickets, this activity encouraged students to work together, discuss their queries and persist in the face of any difficulties.

I was surprised by how few students used their question tickets, yet how well the whole class was progressing with the task:

> *"All are working really well once they get going – it is purposeful. Really good to see [two students] responding well to the tickets and having discussions about when to use them. It looks like none of them have needed to use a ticket, so that is really positive!"* *(LO, L3)*

I believe the use of question tickets encouraged students to ask each other their questions and work collaboratively. Whilst it was not noted in the lesson observation notes, I was asked three questions which were all well-considered. This contrasts to other lessons where I can often be asked 'silly' or 'quick' questions. My mentor and I both noted how students tackled the plenary fraction question confidently after this. It was important that students were still able to ask questions when they needed, and so the use of question tickets seems to be helpful compared to enforced independent work.

**Matching activity**

In lesson four, students were asked to complete a matching activity in pairs. This activity provided further opportunity for student discussion but also helped build student understanding in a more difficult section in the topic of inequalities - representing inequality regions on a graph. As evident below, the class did well in the matching activity:

> *"Lovely matching activity… They've done this really well! They have only really put hands up to check once they are finished. I spoke to [four students] who all agreed that matching tasks made them feel more confident and that an activity was more approachable. They also said they'd now feel happy to try drawing their own regions."* *(LO, L4)*

Matching activities are a useful tool as students may be more willing to attempt a task if they know the answers are in front of them. The process of elimination can help build their confidence in more complicated tasks, such as in lesson four. When combined with pair-work, this can be even better. I found that students asked for help less often, but when they did ask a question, it seemed to be more developed. Students may feel more comfortable to ask for help when working collaboratively, as they may conclude that their question is more 'valid' if neither of them can answer it.

A limitation related to the lesson observation above is that students may have wanted to please or agree with my mentor regarding the use of matching activities. However, both myself and my mentor did observe that the class coped well with this activity. It would be necessary to attempt this style of activity again in the future to compare. One student disclosed in the group interview that a disadvantage of matching activities is that they struggle to see how they got the answer afterwards.

Students seemed to approach these discussion activities with confidence, whilst also showing a "willingness to discuss, reflect and research" (Johnston-Wilder & Lee, 2010a). Through the comparison of lesson observation notes and Johnston-Wilder and Lee's definition of mathematical resilience, I contend that question tickets and matching activities have been shown to improve the mathematical resilience of this class.

I would recommend that this class is given the opportunity to carry out collaborative work beyond working in pairs. I believe this would help to develop their mathematical resilience even further than that progress which is achieved by pair-work. This is linked to the work of Johnston-Wilder and Lee (2010a) who found that a group video project in mathematics helped students "articulate their understanding, work collaboratively and be persistent" (p.12). This type of activity was highlighted as one of several activities that could be used to help develop resilience towards mathematics. Thus, collaborative work could be utilised once or twice a term as a further opportunity for students to learn from one another.

**Confidence building starters**

The use of confidence boosting starters proved to be a helpful start to lesson two and lesson four.

> *"Students are confident giving integer values which satisfy the inequalities and have no issues writing it straight into their books."* *(LO, L2)*
>
> *"Students approach this really well and it's nice to see people like [Student 1] and [Student 2] helping their neighbours who weren't in yesterday."* *(LO, L4)*

I have been recommended to use such starters by other colleagues in both schools I have trained at. It seems that this strategy helps students feel capable and more confident at the beginning of a lesson. This seems to be a straightforward way to build student confidence and hopefully promote engagement throughout the remaining lesson. Without this strategy, some classes will feel overwhelmed in a new topic which they view as 'harder'. This may result in a fixed mindset where students will disengage and stop viewing themselves as 'learners of mathematics' (Johnston-Wilder & Lee, 2010a). Thus, students may show a lack of resilience and find it difficult to develop in their resilience.

It may be argued that lesson starters which are more challenging may provide an opportunity for students to show "persistence in the face of difficulty" (ibid., p.1). However, if students are unable to answer these it may be detrimental for their confidence and learner identities, and thus for their mathematical resilience. As mentioned at the beginning of this paper, mathematical anxiety is a common and consequential issue. Teachers should then use their professional judgement to plan lesson starters which will be helpful and constructive for their students. This is all very dependent on the class and topic being taught. Nonetheless, confidence building starters could provide a helpful way for teachers to build pupil confidence and thus pupil resilience in mathematics.

**Further considerations**

The lesson observation notes were a helpful tool for reflection upon and evaluation of the lesson sequence. There are several changes that I would make when employing such teaching strategies in the future.

Firstly, I would ensure that students are given the opportunity to make adequate notes in their books. In lesson one, my mentor highlighted the importance of providing students with helpful examples for their notes. Students echoed this in lesson two, when numerous students were heard saying, "*I think I need an example with my notes*" (LO, L2). In the group interview, students informed me of their preference of writing notes during lessons and explained how they struggle to remember information if it is provided on printed sheets.

Secondly, I would like to explore the use of Information and Communications Technology (ICT) tools as a strategy to develop mathematical resilience. In lesson four, I used the mathematics website, GeoGebra (2020), to demonstrate how inequalities may be represented on a graph. Whilst the matching activity was the main strategy within this lesson to develop resilience, I am interested in how this use of ICT may have aided students. The use of GeoGebra was found to be positive, as reflected by the following quote:

> *"Great use of the interactive whiteboard to show the shaded regions. It shows the dashed and solid lines for each sign really clearly, and it's lovely that they can spot this for themselves."* *(LO, L4)*

I had previously used GeoGebra with this class whilst teaching the topic of transformations. As a result, they are familiar with the website. In lesson four, GeoGebra seemed to provide a clear and visual explanation for mapping inequalities onto graphs, and so prepared students well for the following matching activity. This follows the recommendations of Johnston-Wilder and Lee

(2010a) who suggest students should be encouraged to use ICT and internet tools in order to be resilient.

Finally, it is important to consider the impact of the learning environment of a mathematics classroom. I doubt that these teaching strategies would have been as effective in promoting mathematical resilience, if students did not feel comfortable or felt like they could make mistakes. I believe this is due to the positive learning environment (LO, L4) created by my mentor, which I was able to teach in. This is consistent with the conclusion of Turner (2018) who recommended that certain teaching strategies such as using 'wrong answers' are not applicable to groups that struggle with confidence issues. I argue that teaching strategies such as 'spot the mistake' would be suitable with this class as a result of the positive learning environment which they contribute to.

## Conclusion

It has previously been assumed that mathematical resilience "develops by accident, if at all" (Johnston-Wilder & Lee, 2010a, p.1). Thus, it is important that resilience is named, recognised and modelled to students regularly (ibid.). This would help students be more familiar with what it means to be resilient and help them recognise this characteristic within themselves. Johnston-Wilder and Lee's definition of resilience has been used as a measure of resilience in this research, however the future development of a measuring tool for mathematical resilience would help to advance this area of educational research.

This action research has helped to show that mathematical resilience may be developed through various teaching strategies. Considering this research, I recommend that teachers incorporate discussion activities and collaborative work into lessons to promote students' mathematical learning. This study has shown that mini whiteboard work, question tickets, matching activities and confidence-building starters are particularly useful tools. As well as leading to more interesting lessons for students, these strategies helped to build mathematical resilience amongst students. Mini whiteboard work helped consolidate understanding quickly, whilst also addressing student misconceptions. Discussion activities using question tickets and matching tasks encouraged students to work together, discuss mathematics and persevere when they were tempted to give up.

This research has also confirmed the importance of a positive learning environment (Turner, 2018). The above activities seemed to work especially well for the class due to the supportive learning environment which had been cultivated. As a result, it may not be possible to replicate the same activities immediately with a different class. Teachers should instead use their professional judgement to employ those strategies they believe would be beneficial and aim to create a purposeful and positive learning environment in their classes.

I hope to use such teaching strategies regularly in my teaching career. I imagine that this will be more difficult when I experience the pressures of external assessment and pupil performance (Johnston-Wilder & Lee, 2010a) as a newly qualified teacher. As outlined by Johnston-Wilder and Lee (2010a), these pressures often result in "a restricted practice of teacher exposition" (p.5) which contributes to mathematical anxiety. Thus, it is important that teachers feel motivated and equipped to use such strategies and so pursue the development of mathematical resilience in students. This will help reduce mathematical anxiety and encourage students to pursue and enjoy mathematics during and after their time in education. Personally, this research has shown me how rewarding it is to pursue creativity and variety in my teaching strategies, despite the pressures that may be present.

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