Grit^2 : Getting Gritty in Mathematics!

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Abstract

Engaging students in tasks that involve elements of risk, error, learner autonomy and tenacity are often promoted as powerful methods for facilitating learning. More guidance is needed for teachers, however, on ways to support young learners who lack the resilience to persevere with such tasks, and who are often frightened to fail. This small-scale study investigated whether participation in self-differentiated mathematical investigations fostered academic resilience strategies for boys aged 7-8 years old. The boys were given a choice of easy, medium or difficult mathematical investigations to work on, then 'rated' and recorded their experiences, and shared the results with others. It was found that partaking in self-differentiated activities had a positive impact on the majority of boys' academic resilience strategies. The findings suggest that a skill such as resilience can be measured, modelled, taught, and improved through teaching and learning initiatives such as: defining resilience, promoting learner autonomy, fostering self and peer reflection, analysing mistakes and targeting methods of feedback.

Glossary

Self-differentiation: This term is used throughout the paper and defined as the process of allowing students to choose tasks that they perceive as appropriate for their own ability.

Resilience: "…*the capacity to rise above difficult circumstances…move forward with optimism and confidence even in the face of adversity…the ability to recover from setbacks.*" (Tough, 2012).

Grit: a combination of perseverance and resilience, the tendency to sustain motivation and passion towards long-term goals (Duckworth, 2013)

Growth Mindset: Based on Carol Dweck's theory of intelligence (2010). The belief that 'success' comes from hard work, learning, determination, and training. It is the opposite of a

'fixed mind set', which is the belief that success is based on innate ability and that you are born with a 'fixed' amount of intelligence.

Introduction

It is currently acknowledged in schools in the UK and around the world, that, in addition to knowledge based subjects, students' social and emotional development is an important aspect of the curriculum. The current National Curriculum in the UK states:

> "School(s) must offer a curriculum which is balanced and broadly based and which:
>
> - promotes the spiritual, moral, cultural, mental and physical development of pupils at the school and of society and
>
> - prepares pupils for the…opportunities, responsibilities and experiences of later life." (Department for Education, 2013, p5)

One of the significant ways many schools are catering for the personal development of their students is by examining the benefits of character education (Pappano, 2013; Parks, Peterson & Seligman 2004; Ritchhart, 2002). It appears that one of the current problems young children face today is that they often avoid or are protected from experiencing failure and therefore have fewer opportunities to develop 'academic resilience' strategies. (Ginsburg, 2011; Hoerr, 2013; King, 2013; Tough, 2012).

As part of my school's commitment to boys' character development, and in conjunction with the International Boys School Coalition, we decided to initiate an action research project to examine the 'fear of failure' culture. Through classroom experiences and feedback from discussions with various colleagues, the idea of exploring whether academic resilience strategies could be modelled, taught and improved came into fruition. The aim was to explore whether a character trait such as resilience could possibly be 'measured', 'taught' and therefore improved or facilitated. Due to the potentially large scope of such a study, it was decided this would be explored through the academic subject of mathematics.

The research question

How can participation in a self-differentiated mathematics programme foster academic resilience strategies in Year 3 boys?

Research context

This action research project was conducted at Dulwich Prep London, an independent preparatory school located in South East London, England, in the United Kingdom. Predominantly a school for boys, (there are girls enrolled in the Early Years section only), the school has over 850 students ranging from ages 3-13. Dulwich Prep London has an outstanding reputation for its academic, sporting, musical and artistic excellence. The school ethos states that the number one priority of the school is the well-being and happiness of its students. Dulwich Prep London (referred to hereafter as The Prep) and its staff are passionate and dedicated to implementing and developing the most current research into how boys learn. Additionally, the school prides itself on building and instilling qualities of character, recognising that they are inextricably linked to intellectual mastery and academic ambition.

At The Prep, some teachers are aware that they have students in their classes who seem to be afraid of, or are deliberately avoiding, failure, and therefore not displaying academic risk-taking behaviours. In some cases, this risk-averse behaviour has affected some boys learning in different curriculum areas. Some lacked the confidence, for example, to make estimations in Mathematics, predictions/hypotheses in Science, and did not try to spell unfamiliar words when writing. Boys such as these need reminding that mistakes are a natural and integral part of the learning process. As well, they need to learn how to be more resilient and persevere when faced with challenges and setbacks (Duckworth, 2011; Dweck, 2010; King, 2013).

Literature Review

High levels of emotional intelligence have been shown to be important predictors of future academic success (Claxton, 2007; Duckworth, 2013; Ritchart, 2002), often, it seems, more so than Intellectual Quotient (IQ). Recently, to support the development of emotional intelligence, many schools have started to teach skills such as resilience as part of their character education programmes (Duckworth, 2013; Goleman, 2013). In the UK, skills to promote resilience are now recognised as being essential to the healthy development of every child, and have recently been included as an additional element of the *statutory requirements* of the Early Years Foundation Stage (EYFS) framework. The EYFS outlines these skills in its section on the Characteristics of Effective Learning. These include "…showing a 'can do' attitude, taking a risk, engaging in new experiences and learning by trial and error." (Development matters, 2014, p6.) A large body of educational research supports this

emphasis on building resiliency, arguing that risk taking and failure should be viewed as healthy aspects of learning. (Duckworth, 2013; Pappano, 2013; Tough, 2012).

> *Active and engaged learning involves the risk of error. Schools must encourage students to take risks, and provide support for interpreting and building on error. It is the quality of the risk taken - the potential that the risk offers for learning- that should be rewarded, rather than the glossiness or ease of success* (Eckert, Goldman, & Wenger, 1996, p.5).

Recently, the encouragement of risk-taking and determination during challenging learning tasks has been investigated (Hoerr, 2013; Jones, 2012). Consequently, schools are looking at how educators can develop and foster children's perseverance strategies. Whilst the experience of failure is often tainted with anxiety (Lupton and Tulloch, 2002), there is a weight of research purporting that mistake-making is an integral part of academic success (Lupton & Tulloch 2002; Tough, 2012; Peacock, 2008; Hoerr, 2013; Jones, 2012). What matters, it seems, is knowing how to fail effectively by reflecting upon and learning from mistakes (King, 2013).

From the literature surrounding resilience, common traits of resilient behaviour continue to emerge. All of them could be grouped accordingly to match the *Seven traits of productive persistence* (Stano, 2012).

> *Productive persistence…is an umbrella expression used to describe the interplay between motivation and engagement, manifesting itself in the mindsets and skills that allow students to…withstand challenges and setbacks to persevere towards achieving …goals* (Stano, 2012, p.2).

The Seven traits of Productive Persistence

1. **Theories of Intelligence**

2. **Self-efficacy**

3. **Attributions**

4. **Belongingness**

5. **Values and Interest**

6. **Goals and Mastery**

7. **Self-regulation**

(For a more detailed explanation of these traits, see Appendix 1)

From the literature reviewed, findings suggest that the continued development of grit and resilience in education is valuable. What emerged as puzzling, however, is that whilst documents in the UK such as the EYFS have listed risk taking, failure and resilience strategies as imperative aspects of 'The Characteristics of Effective Learning', the recently reviewed National Curriculum documents no longer appear to have a section detailing the importance of resiliency skills. Furthermore, despite the large scope of research into the importance of self-regulation and self-efficacy as large factors in learner success (Bandura, 1991; Duckworth, 2011; Vygostky, 1978), little can be sighted in relation to the term 'self-differentiation.' Subsequently, more investigation is needed regarding whether self-differentiation strategies affect resilience development.

Methodology

For this study a critical realist approach using action research was chosen. The research design was flexible, using both qualitative and quantitative techniques. Action research is sometimes known as an 'emancipatory' social research method, as it requires the instigation of change (McNiff, 2010; Robson, 2011).

Participants

This investigation used non-probability sampling by choosing a convenience sample of the school student population. The participants were 17 Year 3 boys aged between 7-8 years old. All but one member of the class volunteered to participate. The action research project was explained to parents at a curriculum evening and both parent and son were asked to complete a form of voluntary consent to participate. The guidelines outlined by the British Educational Research Association (BERA) ethical guidelines for educational research were followed.

The Action

The intervention commenced with several lessons on defining the word resilience and identifying what resilient behaviour looks like in the world, the school and our classroom. The boys came up with slogans for what the term resilience meant to them, and we created a class wall display.

In the lessons that followed, mathematical 'investigation' cards (Crown, 2000) were presented to the boys in three colour levels of difficulty: green, yellow and orange (green

being the easiest, then orange, with red being the most challenging.) The green investigations were aimed at 5-7 year olds, yellow investigations were aimed at 7-9 year olds and orange investigations were aimed at 9-11 year olds. The boys chose which cards to work on independently, and noted this along with their workings on a recording sheet (see Appendix 2). After working through an investigation card, the boys rated the problem out of 10 (1 being the easiest, 10 being incredibly difficult). The boys could revisit the investigations in subsequent lessons, referring to their recording sheet for reflection on past trials and successes.

The one-hour long sessions (between 2-4 per month) were conducted over the Autumn and Spring terms of 2013-2014. Subsequent lessons involved discussing example investigations and sharing problem-solving strategies in collaboration with others, before having the opportunity to revisit problems or attempt new investigations. Growth mindset values (praise for effort and demonstration of resilience) were actively promoted through teacher praise, class discussions, marking and feedback. At the end of the intervention, a small selection of boys were asked for feedback as to what they liked and disliked about the process, and whether they felt their academic resilience in mathematics had improved over the course of the study.

Data collection

Data collection used both qualitative and quantitative techniques. To improve credibility and rigour, data triangulation was employed, and a variety of data were collected using a collaborative approach. Data included work samples, observation notes, survey findings and interview transcripts.

Grit slogans

The students defined the term resilience and the slogans were used as both an introduction to the intervention, and as data on perceptions of resilience. (See Appendix 3).

Grit survey

To establish a baseline measure for how resilient the students were at the beginning of the intervention, a student Grit Survey (see Appendix 4) was administered (adapted with permission from Hoerr, 2013). The 10 question survey was modified so that it was written in 'child friendly' vocabulary with simple images to assist in answering the questions, which used an ordinal scale known as a Likert Scale (Bell, 2010). To assist students with reading

difficulties, the survey was read aloud, and time was allocated for questions and clarifications. Use of the Likert Scale allowed responses to be scored numerically to give each child an overall 'grit score.' The survey questions were randomly allocated to avoid pattern detection. The same survey was repeated at the end of the study to allow for direct comparison of responses, and to ascertain whether any improvements had been made to the boys' initial grit score. An improvement in scores would suggest that participation in the program had fostered academic resilience strategies in the students.

Mathematics Investigation Recording Sheets

The students were given recording sheets to keep a numerical and reflective record of their participation in the mathematical investigations. Thematic coding against *The Seven Traits of Productive Persistence* (Stano, 2012) was used to ascertain whether any trends or patterns emerged from the student responses that illustrated aspects of resilient behaviour.

Observations

A variety of methods of observation were employed.

Interviews

While working on the tasks, many of the students were informally questioned about their work and prompted for feedback regarding strategies used, how they would decide what to do next, what they had learnt from previous investigations and how easy or difficult they were finding the tasks. At the completion of the intervention, four students of varied mathematical ability were interviewed regarding their experiences and perceptions of the intervention. To allow for a broader set of responses, these students were chosen for the interview based on their standardised Performance Indicators in Primary School (PIPS) scores in the domain of Mathematics. Student 1's standardized score was 'above average', Student 2 and 3 'average' and Student 4 'below average.'

Data Analysis

The qualitative data obtained were coded using thematic coding analysis (Robson 2011). Thematic coding involved focusing on categorizing data into common groups by looking for patterns and recurring trends that suggested the boys had developed some resilience strategies. The categories for the groups were based on Stano's (2012) *The Seven Traits of Productive Persistence* (abbreviated to *Productive Persistence* herein). Data triangulation was used in order to give credibility and rigour to the findings. Summative analysis of the

boys' recording sheets, questionnaire results and audio transcripts was used to determine whether the intervention had affected the development of resilience strategies in mathematics. Written and audio observations and interviews were transcribed into word documents. These recordings and the students' comments from the mathematics investigation recording sheets were also analysed and grouped into examples of *Productive Persistence* (Stano 2012) to help identify examples of resilient language and behaviours.

Key findings and discussion

Grit Survey

Analysis of the Grit Survey (Hoerr, 2013) indicated that the majority of boys in the study showed an increase in their grit scores between November 2013 and March 2014. This trend suggests that the intervention had a direct impact on the majority of the boys' resilience strategies.
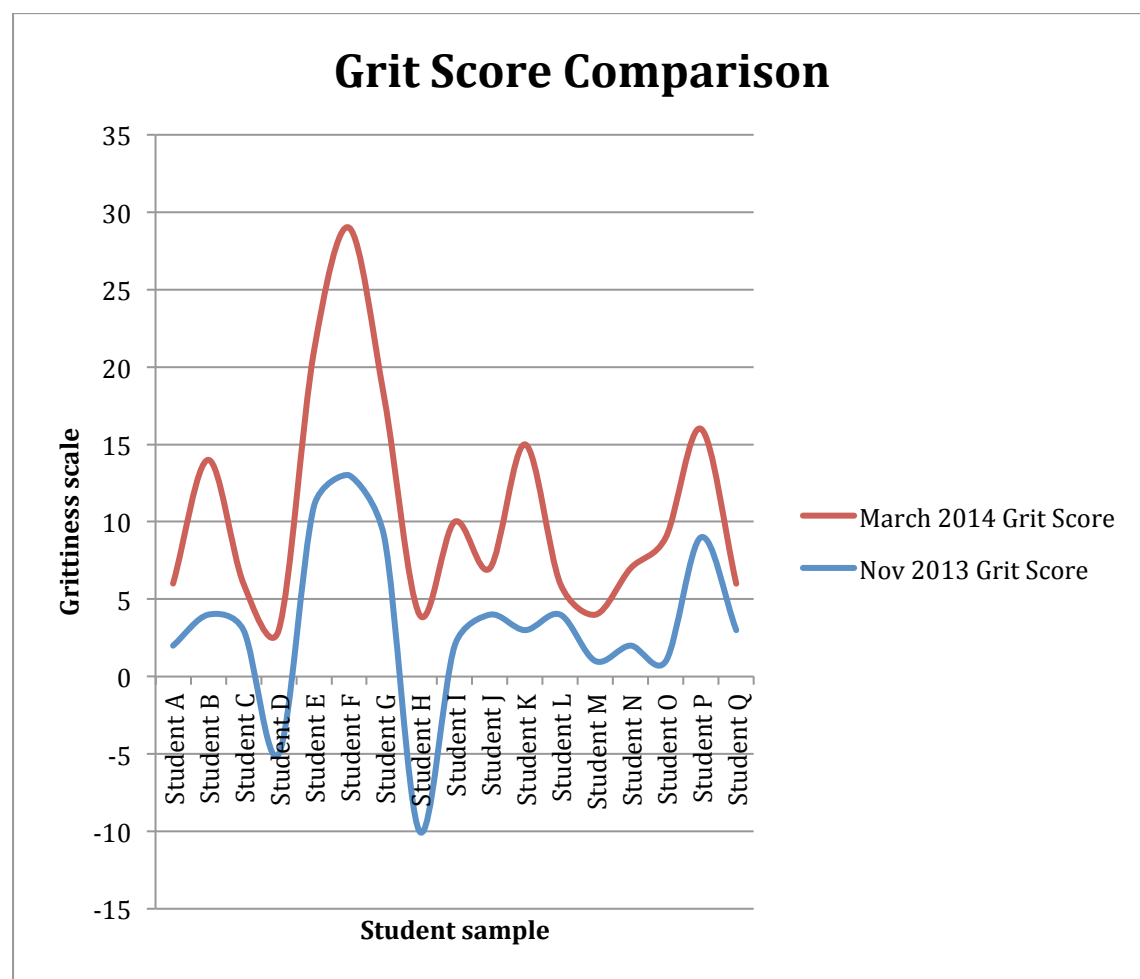
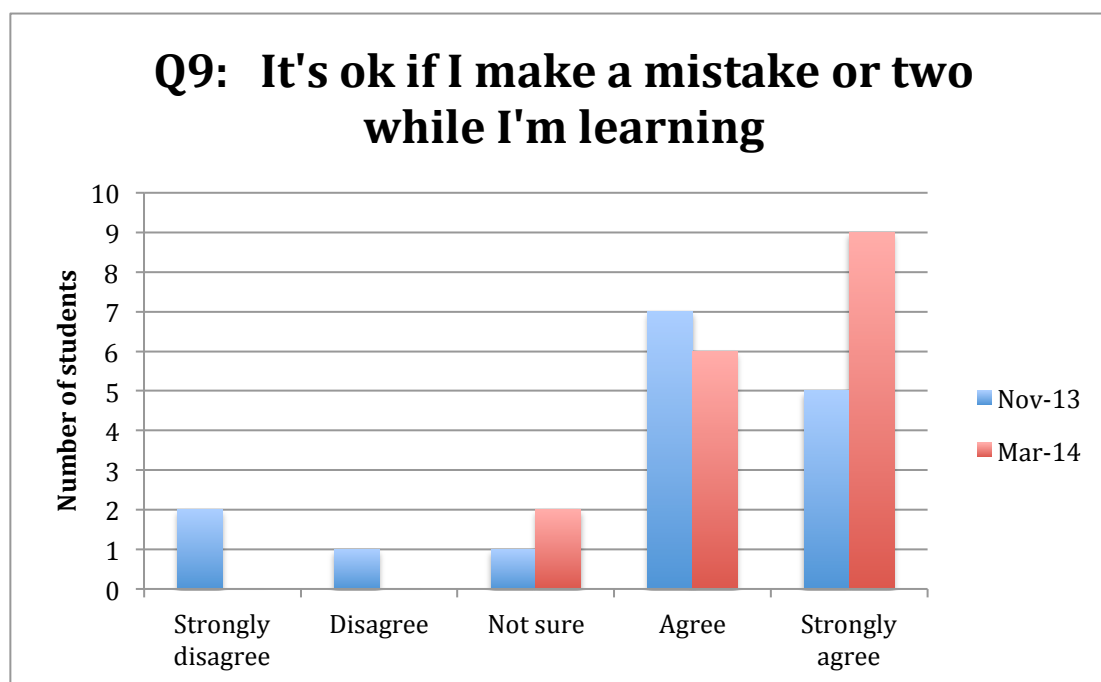Graph 1- Pre and Post Grit Survey Scores

Grittiness scale

18 and above = Extremely gritty

12-17 = Actively developing grit
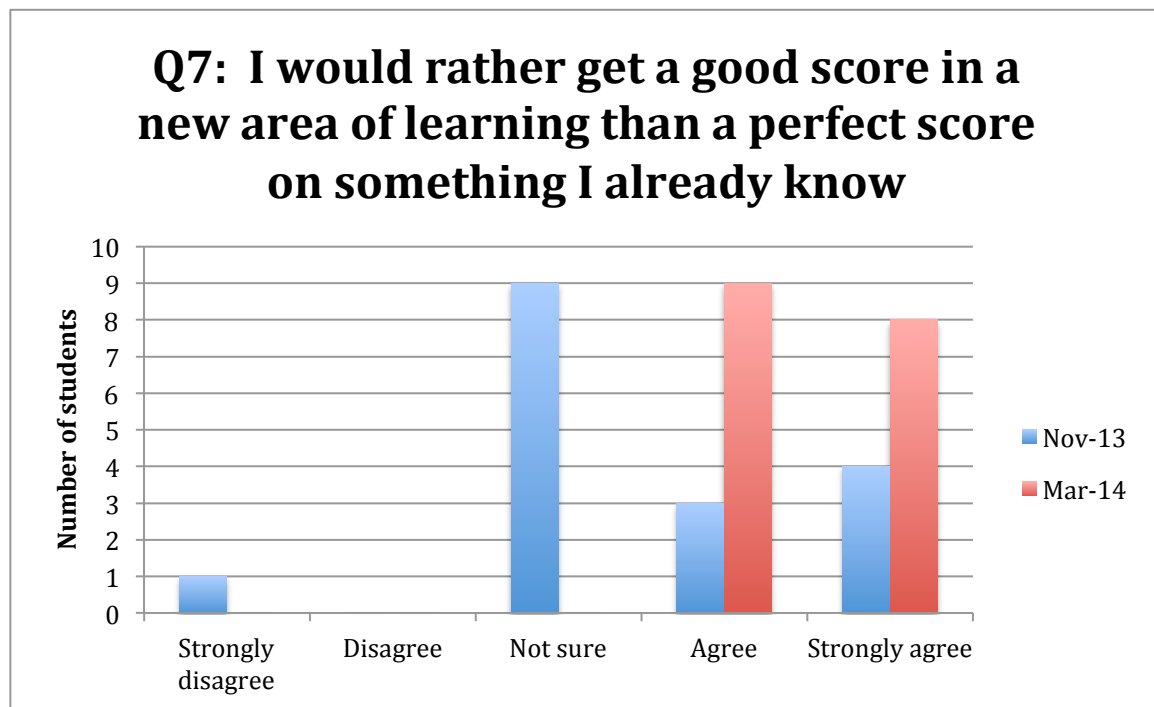
Less than 12 = Early stages of developing grit

Graph 2- Reponses to Survey Question 9

Responses to the survey questions were also analysed separately, and trends indicated very positive results in terms of growth in resilience. For example, when asked whether it is ok to make mistakes when learning (a growth mindset belief), the boys' responses had changed markedly from the beginning of the intervention in November 2013.

Q9: It's ok if I make a mistake or two while I'm learning

Number of students (y-axis: 0 to 10)

Categories: Strongly disagree, Disagree, Not sure, Agree, Strongly agree

Legend: Nov-13 (blue), Mar-14 (red)

- Strongly disagree: Nov-13 = 2, Mar-14 = 0
- Disagree: Nov-13 = 1, Mar-14 = 0
- Not sure: Nov-13 = 1, Mar-14 = 2
- Agree: Nov-13 = 7, Mar-14 = 6
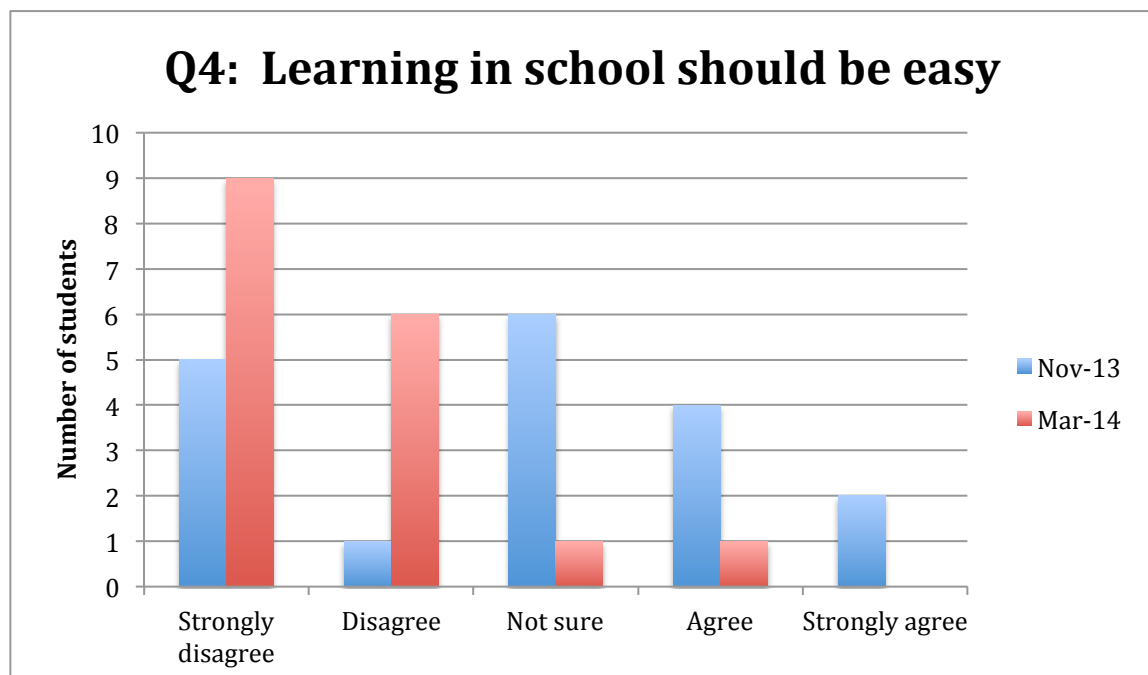- Strongly agree: Nov-13 = 5, Mar-14 = 9

The graph above shows most boys' attitudes towards failure improved, indicating growth mindset and mastery values (see Appendix 1).

Graph 3- Responses to Survey Question 7

Q7: I would rather get a good score in a new area of learning than a perfect score on something I already know

Number of students (y-axis: 0–10)

Categories (x-axis): Strongly disagree, Disagree, Not sure, Agree, Strongly agree

Legend: Nov-13, Mar-14

The response to this survey question indicated that almost every student displayed a growth mindset (Dweck 2010) towards learning. The fact that the boys would rather do well (around 80 percent) on a new learning area than get 100 percent in a topic that they already know indicates they believe that effort is more important than outcome.

Q4: Learning in school should be easy

Number of students (y-axis: 0–10)

Categories (x-axis): Strongly disagree, Disagree, Not sure, Agree, Strongly agree

Legend: Nov-13, Mar-14

Graph 4- Responses to Grit Survey Question 4

In Graph 4, the most popular response in March 2014 was to strongly disagree. It was very positive to see that most students did not think learning should be easy, in fact, quite the opposite. This would suggest they wish to be challenged in order to learn. This finding correlates with both Duckworth's (2013) and Hoerr's (2013) research into grit, that suggests students need to be taken out of their comfort zone in order to develop effective resilience strategies. The findings also support Vygotsky's (1978) theory of the Zone of Proximal Development.

There were many more examples in other survey answers of positive trends in developing resilience. Their inclusion, however, is limited by the small scope of this paper.

Whilst these graphs clearly show some very promising indicators that the intervention had a positive impact upon the boys' resilience strategies, important findings also came from analysing the student mathematical investigation recording sheets, observations and interview responses.

Mathematics Investigation student Recording Sheets

The mathematical investigation recording sheets were analysed in two different ways. Firstly, a quantitative numerical analysis was taken of the number of attempts made versus the number of question levels attempted (easy, medium or hard).

One of the key findings from the numerical data was that the vast majority of boys attempted the orange (difficult) problems. These were problems outside their age range, and illustrated that the boys wanted be challenged and taken outside their comfort zones (Hoerr 2013). In normal classroom situations, students are often unlikely to be given opportunities to attempt challenging questions because teachers will tend to provide investigations matched to each student's ability.

Another key finding was that, despite many of the boys getting several questions incorrect on their first attempt, this did not seem to affect the number of future questions attempted, nor deter them from trying the same or similar problem again. Although many students found something hard, or failed on their initial attempt, they made repeated attempts to solve the problem. Their written comments support this finding. For example, one student wrote, "it took a long time but I got there in the end." Another commented that, "this was very easy to guess, but difficult to get right." Another wrote, "this was very hard, I tried it lots of times." These comments reflect growth mindset (Dweck 2010) values towards learning.

The written comments from the student recording sheets were grouped according to the seven themes of *Productive Persistence* (Stano 2012). Many of the responses were not mutually exclusive and mirrored several themes simultaneously. They also provided an insight into the metacognitive resilience strategies adopted by the boys.

Values and Interest

The majority of students were interested in the task and attributed an incredible amount of value to them. A few examples from the student interviews and record sheets are given below.

"Well I wanted to finish this one because…there were too many answers…then I wanted to give up …it was so tiring. Now (in a subsequent lesson) I'm not that tired and I feel refreshed so I can do it again…"

"It was quite hard and… it was quite fun. I didn't really want to give up. I always want to finish a good challenge. I don't think I'm going to put it back until I've finished."

"I think this is what I'm going to do but it will take quite a long time."

"I would look at how hard they are, and then I would choose an easy one to prepare for a hard one."

" We started with a hard one, and then did an easy one to cool down."

It was fascinating to see how many students remained engaged and on task during these investigations, despite there being no extrinsic motivators such as tangible rewards. Their main motivators were simply to finish the task itself and experience success in their learning.

Goals/Mastery

There were many instances of mastery learning taking place during the intervention, reflected in comments such as, "I think I should do one like it again," and "it took a long time but I got there in the end." "I start with an easy one to …get warmed up and then I can do orange or yellow." Additionally, four students were interviewed in depth about how to improve in mathematics, and all of them suggested practising at home and using apparatus or prompts at school.

From the results of the grit survey, the overwhelming majority of boys said they would rather get a good score on a new area of learning than 100 percent on something they already know, indicating mastery learning attitudes.

Self-regulation

Self-regulation skills allow students to stay on task, avoid distraction and navigate obstacles as they attend to their learning. (Stano, 2012; King, 2013). From both the written responses and the interviews, there were many examples of self-regulatory behaviour:

 "This was confusing me but I figured it out soon."

"You have to take your time or otherwise you might get the answers definitely wrong."

 "I tried the first one and it was too hard. I then tried another one to see if that one was fine and that… was, so I just kept on orange ones…"

"I thought it (a yellow question) was going to be very difficult but then I figured out a good method of doing it and then … it was actually quite easy."

Self-regulatory behaviour was also evident from teacher observations. Students often used apparatus or classroom prompts and posters to assist in problem solving, or swapped the investigation card for an easier or harder task. Boys were seen referring back to previous notes for both tracking and reflection on similar tasks. I was impressed with the majority of boys demonstrating self-regulation skills, although, as would be expected, some students also needed teacher prompting at times to stay focused. When interviewed, several students expressed a preference for having choice, as they liked the variety of problems and felt capable of choosing something they were motivated to finish. Student 2 said "…if you didn't have a choice and someone chooses them for you it could be too easy or too hard." The power of choice through differentiation is something I would like to explore further in other curriculum areas.

Conclusion

'Success is not final, failure is not fatal: it is the courage to continue that counts.'

Sir Winston Churchill (1874 – 1965)

Resilience is a trait that has enabled humanity to endure. Churchill made reference to this during a time in which rapid global change was taking place in World War II. Resilience skills were, quite possibly, at their most needed during this period of history. The same could be said, however, for the 21st Century. Many students will embark on career paths that have not yet even been conceived. Teachers have an important role to play in developing emotional intelligence skills, to help pupils confidently navigate their way through this ever-changing world.

The intervention in this action research study appeared to have a positive impact on the boys' academic resilience skills, and in particular, on their ability to problem-solve, to persevere when facing a challenge, and to alter their preconceived ideas about learning. Most boys showed improvements in their academic resilience strategies. The outcomes from this project suggest that character skills such as grit, determination and perseverance can be explicitly taught, influenced, adapted and improved.

Implications for Practice

By exploring whether educators can foster academic resilience strategies in the classroom, I have discovered some ways in which we can enhance this aspect of students' character development. Teachers who would like to investigate different strategies in their schools could consider the following:

- Reflect upon your own behaviours, feedback and marking procedures, as these all markedly impact upon student learning. It is important to remember that we give both conscious and unconscious messages through our actions and words. Think about whether you're promoting growth or fixed mindset values in your classroom.

- Create more occasions for peer group tasks, and reflection, as collaborative learning opportunities and the chance to attempt tasks repeatedly seemed to improve student perseverance and motivation.

- Student recording sheets could be implemented into everyday practice, as these were an effective medium for reflection and error analysis. Giving regular opportunities for students to rate the difficulty level of their work is also beneficial and can be done in many ways. For example, using smiley faces, giving numerical values or colouring with a traffic light system.

- Provide opportunities for students to have more autonomy over their learning. The boys in this study appeared to enjoy having greater variety and choice of tasks. Some, however, found too much choice overwhelming, which suggests that the amount of choice needs to be considered carefully.

- Provide students with a risk-taking day or week. Parents could be invited to participate in various physical and academic challenges with their children and share their own experiences of failure and overcoming setbacks to achieve success.

- Create a grit hall of fame with past pupils/ old boys/teachers names on an honour roll listing their achievements/successes through cases of exemplary perseverance. This could also include famous people who have overcome challenges such as dyslexia, to become very successful.

- Provide solution cards that show the answers and the working out, corresponding with each investigation card, so that students could peer or self-assess their work.

- Allow greater class time for reflection, discussion and sharing of problem solving strategies. Consider introducing a true grit award as part of weekly assemblies. Celebrate individuals who have demonstrated resilience in their learning and enable them to share their strategies with others.

The suggestions given here represent a small sample of strategies that teachers could employ. It seems worth considering teaching about resilience even in the very earliest years of schooling. The sooner educators can influence children's understanding of learning, the greater the likelihood of encouraging a growth mindset, which will help them to reach their full academic potential.

Fostering resilience ultimately begins with a paradigm shift of educational beliefs. There are no simple programmes or teaching tools that we can roll out into schools as a 'quick fix' answer to our risk-averse society. Rather, fostering resilience begins with changing *how* we teach, rather than *what* we teach. We need to be living, breathing, acting examples of resilience. I encourage my peers, colleagues and the wider school community to share in this exciting learning journey, and to engage with and apply this insight to their own personal context. In doing so, we can help our boys to go forth in the world as the responsible, confident, caring, successful global citizens we wish them to be.

"The greatest glory in living lies not in never falling, but in rising every time we fall"

Nelson Mandela (1918-2013)

Reflection

How often do teachers let their students experience discomfort in their learning and provide opportunities to discuss learning from failure? How often do we let them reflect upon their mistakes, analyse them in detail, and allow them to make repeated attempts? Are we promoting a school of growth or fixed mind-sets? Are we rewarding students for their innate intelligence or for their achievements and the work ethic they took to get there? These were

some of the questions I discussed not only with my fellow colleagues but grappled with myself during this action research process.

The research process was extremely challenging- who knew that when I undertook a project on resilience I was going to have to test my own resilience strategies to their maximum capacity! Juggling full time work, adjusting to teaching a new Key Stage and teaching team, planning a wedding, (I managed to get to the aisle on time), continuing my Masters and interviewing for an internal job promotion- these were just some of the hurdles I encountered along the way.

The process has been an incredible learning journey for me as a teaching practitioner. The initial response from the students, parents and peers was so positive, and I felt excited embarking on something new and at times, scary. After all, I had to face up to my own aversion to failure- what if I found out nothing exciting from this research? This is all a natural part of learning, as I would soon discover.

From the literature review I came to understand that it is important for researchers to publish all results, even if some are not positive, so that others can learn from their experiences. The part of the process I enjoyed the most was taking the time to observe and interview my boys in action- what a fascinating bunch of learners they are! It was so powerful as a teacher to record their responses and reflect on their experiences with them, taking the extra time to really listen. It was also a challenge to really 'let go' and give the boys full autonomy over their learning- an intimidating process that was at times chaotic and noisy but so rewarding.

I particularly appreciated knowing that my IBSC colleagues all around the world were experiencing similar things to me, and being able to 'hangout' on a virtual video conference call was such a fantastic level of support, as were the regular emails and website updates from my team advisor.

I would recommend action research as a positive, exhilarating way to reflect on best practice. I have barely scratched the surface in terms of what could be done; the possibilities for exploration in resilience education appear to be vast. I look forward to the next phase of the research process, and developing the necessary steps to move resilience education further forward in our school.

Acknowledgments:

"You never fail until you stop trying."

― Albert Einstein

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Appendix 1: The Seven traits of Productive Persistence

1. *Theories of Intelligence*

2. *Self-efficacy*

3. *Attributions*

4. *Belongingness*

5. *Values and Interest*

6. *Goals and Mastery*

7. *Self-regulation*

(Stano 2012, p.4)

Theories of intelligence

Based on Carol Dweck's (2009) theory of intelligence, students with 'productive persistence' endorse her growth mindset theory and therefore persist longer when faced with academic challenges and setbacks (Sparks, 2013;Stano, 2012).

Dweck believes that people fall into two categories of mindset, 'fixed' and 'growth,' both of which are based upon how the individual perceives their intelligence to have developed be it from birth (fixed) or from learning experience (growth). Understanding such mindsets can improve academic achievement. This is recognised in the 'Brainology programme', an online teaching tool aiming to 'coach' children towards growth mindset attitudes. It is currently implemented in over 600 schools in the U.S.A, and is branching out into middle school mathematics curricula (Sparks, 2013).

Self- efficacy

Can be defined as confidence in one's own ability to achieve a goal (Bandura 1997). Recent studies have substantiated that students' perceptions of their own ability are a more powerful predictor of future academic performance than their measured ability. (Hattie, 2012; Stano, 2012). Closely linked to this, there have been many studies on primary (ages 5-12) conceptual understandings of mathematics which argue that children's own self-esteem and mind-set (both contributors to self-efficacy) can have a direct impact on mathematical understanding and performance (Chiu, 2011; Sullivan, Tobias & McDonough, 2006; Voutsina, 2012).

Attributions

Can be seen as the reasons students give for their success or failure (Stano, 2012). Students with a resilient mind-set use attribution to understand their own learning. They recognise their mistakes and shortcomings and reflect upon them effectively. Students without attribution abdicate their achievements or faults to an external source, such as blaming the teacher, task or school (King, 2013).

Belongingness

According to research (Goodenow, 1992; Furrer and Skinner, 2003; Stano, 2012) when students believe they belong to part of an academic community and feel socially connected to their peers, they will generally show more motivation and enthusiasm towards given tasks.

Values and Interest

Productively persistent students view the outcome of the task as extremely important, and see academics as integral to the future (Stano, 2012). Students who are resilient will show intrinsic motivation for wanting to complete a task, and will make several attempts in order to find the solution/experience success (King, 2013).

Goals/Mastery

Resilient learners place a strong emphasis on the importance of mastery (Duckworth, King, Martin and Marsh) and understand that learning is often a gradual, lengthy process aimed towards achieving a specific goal. Akin to training for a marathon the idea behind mastery learning is to imagine that the brain is like a muscle that can be strengthened with repeated exercise. This echoes Gladwell's (2008) argument that a person must practice for at least 10,000 hours in order to 'master' a skill.

Self-regulation

Self -regulation skills allow students to stay on task, avoid distraction and navigate obstacles as they attend to their learning (King, 2013; Stano 2012; Vygotsky, 1974). Self-regulation is a particularly important element of 'inquiry-based learning' theories. (Bandura, 1991; Stano, 2012; Vygostky, 1974) Significant research argues that development of self-regulation and learner autonomy are particularly pertinent to boys education, as these skills develop much later in boys than in girls (James, 2007). They therefore need explicit modelling and teaching of these skills as well as regular opportunities to engage in challenging self-control tasks in order to become autonomous, confident learners (Duckworth, 2013; James, 2003).

Date	Card number	Card Colour (tick)	Did you... (Please tick)	Difficulty rating /10 and comments	Answers/workings
		🟢 🟡 🟠	Read it ☐ Started it ☐ Put it back without doing it ☐ Finished it ☐	1 2 3 4 5 6 7 8 9 10 Easy peasy middle man cool challenge terrifically tricky brain drain!	
		🟢 🟡 🟠	Read it ☐ Started it ☐ Put it back without doing it ☐ Finished it ☐	1 2 3 4 5 6 7 8 9 10 Easy peasy middle man cool challenge terrifically tricky brain drain!	
		🟢 🟡 🟠	Read it ☐ Started it ☐ Put it back without doing it ☐ Finished it ☐	1 2 3 4 5 6 7 8 9 10 Easy peasy middle man cool challenge terrifically tricky brain drain!	
		🟢 🟡 🟠	Read it ☐ Started it ☐ Put it back without doing it ☐ Finished it ☐	1 2 3 4 5 6 7 8 9 10 Easy peasy middle man cool challenge terrifically tricky brain drain!	

Appendix 2: Maths investigation student recording sheet

Appendix 3

Gritty slogans

The slogans created by the students indicated that they felt resilience was a personal experience to them that involved some level of discomfort, endurance and perseverance. The slogans were grouped into four categories that according to research could be defined as examples of resilient behaviours. (Hoerr 2013, Duckworth 2013, Ginsburg 2011)

Resilience involves struggle	Resilience is psychological	Resilience is physical	Resilience means repeated attempts when facing failure
When you fall, always bounce back Be strong Get back up	Follow your heart Believe you can do anything! Mentally tough Believe you can Try your best	When you fall, always bounce back Get back up	Why stop? Carry on Keep going Never give up Try again Don't stop keep going Persevere Keep trying

Appendix 4

Student Grit survey

Tick one of these columns for each answer	NEVER (I strongly disagree with this)	NO (I disagree with this)	I'm not sure	YES (I agree with this)	ALWAYS (I strongly agree with this)
1. No matter how hard a task is, I keep trying					
2. I would rather practice something I am good at than try to learn					
3. I am often distracted when things are hard					
4. Learning in school should **always** be easy					
5. I usually work harder than my classmates					
6. It is important to me that I don't make mistakes					
7. I would rather get a good score (80%) in a new area of learning than 100% on something I already know					
8. Learning **must always** be fun.					
9. It's ok if I make a mistake or two while I'm learning					
10. If I find something difficult, it makes me want to practise it more					

Source: Hoerr, T. (2013) 'Student grit survey' from *Fostering grit: how do I prepare my students for the real world?* Alexandria, USA: ASCD. (Figure 2, page 19) Copyright © 2013 by ASCD. Adapted with permission. All rights reserved.