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DEVELOPING COACHES FOR MATHEMATICAL RESILIENCE

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Abstract

The construct 'Mathematical Resilience' [1] has been developed to describe a positive stance towards mathematics that enables learners to develop approaches to mathematical learning which enable them to overcome the barriers and setbacks that can be part of learning mathematics for many people. A resilient stance towards mathematics can be engineered by a strategic and explicit focus on the culture of learning mathematics within both formal and informal learning environments. As part of that cultural engineering, we have developed the notion of coaches specifically to support emergent resilience. The work described here is focused on developing coaches who can work beside learners, helping them to think about and use resilient learning ideas when facing difficulties in mathematics. Coaches develop a culture of 'can do' mathematics which works to counter the prevalent culture of mathematics helplessness and mathematics anxiety in the general population when faced with mathematical ideas. The coaches are not required to *know the answer* but rather to know ways that might yield an understanding of the mathematical ideas involved and thus lead to an answer.

This paper discusses the outcomes of a pilot course (April to June 2013) designed to develop 'coaches for mathematical resilience'. The course recruited 11 participants who regularly work with apprentices, both young and more mature, in a work-based environment and who are required to learn and use mathematics as part of their on-going training. They became part of the course due to recognition of their own lack of knowledge about how to overcome deep seated antipathy to mathematics in themselves and in those with whom they work.

The data confirms that in order to become an effective coach, an individual first needs to develop their own personal mathematical resilience, work through their own anxieties and negative stance towards mathematics in a safe and collaborative environment, before they can coach a learner to develop as a resilient learner of mathematics. An environment that enables an individual to learn to be a mathematics resilience coach will need to expose the learners to mathematical ideas in order to enable participants to consider and manage their own reactions to mathematical ideas and reflect on how to help someone else find the resources to overcome their own barriers to learning mathematics.

Keywords: mathematics anxiety, learned helplessness, mathematical resilience, coaching

1 UNDERSTANDING MATHEMATICS UNDER-ACHIEVEMENT FROM AN AFFECTIVE VIEWPOINT

According to psychological research [for example, 2] repeated exposure to unpredictable and inescapable stress can lead to learned helplessness, anxiety, inactivity, and fear.

We consider the mathematics problem as people avoiding mathematics in order to avoid a repeat of previous suffering. We propose that this is not in the nature of mathematics itself, but a result of one or many negative experiences that lead to mathematical avoidance as a form of psychological protection.

The construct Mathematical Resilience [1] has been developed to describe a positive stance towards mathematics, one that enables learners to develop approaches to mathematical learning, to overcome the barriers and setbacks that are part of learning mathematics for many people.

1.1 Good stress, bad stress

Stress experienced by a learner can be productive, "good stress", based on external and internal stimuli that are mild or moderately challenging but limited in duration; stress such as this can result in a sense of mastery and accomplishment, often experienced positively, even exciting. However, situations involving more prolonged, repeated, or chronic stress, which may be experienced as uncontrollable or unpredictable, involving a lower sense of mastery or poor adaptability, lead to a

greater stress response. The 'primitive' brain stem is involved in physiological and emotional responses to stress, thus invoking fight, flight or freeze responses in extremis. Neurobiological evidence shows that, with increasing levels of emotional and physiological stress, prefrontal functioning decreases, cognitive control reduces and, consequently, there is increased risk of maladaptive behaviors, such as avoidance, helplessness and anxiety. (See [3].)

1.1.1 Example of mathematical helplessness in a mother of a primary school pupil

To illustrate the impact of mathematical helplessness, we draw on the journal of 'Heather', a young mother whose helplessness developed from an accumulation of negative mathematical experiences at school. Here is Heather's description of one negative experience with school mathematics:

"when i was her age i remember sitting in my yr.6 class room, my teacher was miss jackson and we were doing maths we were working on long division, i got a red cross on some of my work when i checked on the calculator the answer was correct, (mmm) this puzzled me so when i questioned my teacher she said it was because my working out was wrong and made me feel stupid in front of my peers when i explained (translated) my methods."

Heather, as a child here, had demonstrated mathematical resilience in that she had been willing to 'have a go', had reached a correct answer and asked for clarification when she was puzzled by the teacher's marking. The teacher's response in this situation undermined the child's existing mathematical resilience, and contributed to the child experiencing loss of social esteem, loss of willingness to ask questions in the future and thus loss of innate mathematical resilience.

Here is part of Heather's account of her experience as a mother wanting to support her daughter from a position of personal mathematical helplessness and anxiety.

"throughout the years when i've worked with my daughter on maths homework its been a combination of falling out, shouting, tears , avoidance feeling stupid on both parts her putting herself down me trying to restore her confidence but both of us to[o] tense and stressed for it to make any difference, of recent years she began laughing at me for using a calculator and not understanding, pointing out what year she is in and that i need to go back to school."

In this account, Heather describes a desperately stressful situation in which her attempts to help, as she believes she should, lead to further embarrassment and undermine her role as mother, and further enforce her self-identity as helpless in the face of mathematics. Heather's perception of stress involves several factors, including the availability of resources, beliefs and expectations. Heather had resources from her daughter's school; she had the expectation that, as a mother, 'she should be able to help' as she did with other subjects; and her own self-image was of total failure in relation to mathematics. When Heather sought help from us, she was offered a resource, in the form of a mathematics dictionary. We encouraged her to be aware of her own everyday use of mathematics, and to focus her attention on her role as 'curious, supportive, listening mother' rather than inadequate mathematics 'expert'. With no extra mathematical knowledge, the change was dramatic.

1.1.2 Mathematical resilience in the same mother a few months after 'treatment'

According to Seligman [2], the cure for learned helplessness caused by stress is to use the natural stress responses in which the first stage is curiosity and excitement; as long as the learner maintains control of the duration and intensity of the stressor, the level of stress remains productive.

Here is an extract from Heather's journal of her subsequent, resilient behaviour, and how she supported her daughter in developing mathematical resilience.

"one day after she came home from school she curiously asked me for the text book they had been working from that day in school, she confidently flicked the page open to an angles section where there was a page full of lines in all directions, and said "we were doing this today but i don't get it " so i said well lets have a look then, with a few minutes she understood, it turned out that all that really confused her was the layout of the page as it was full of lines set up in twos connecting at one point and were heading in all sorts of directions"

Heather's response is one of getting out the home copy of the school text, supportive curiosity and listening; there was no need for her to input any mathematics. Her daughter expected Heather to be helpful and supportive without knowing current school mathematics. If she needed any maths help, the daughter would contact a maths expert with her mother's support and encouragement. Thus the home situation is no longer stressful and becomes one of growth in small steps.

1.2 What does mathematical resilience look like?

Resilient students can be thought of as students who succeed in school despite the presence of adverse conditions. What do they look like? Resilient students: are adaptive; able to cope with ambiguity; expect problems and challenges; solve problems logically and flexibly; look for creative solutions to challenges; are curious and learn from experience; have an internal locus of control; are aware of their feelings; have a strong social network and are able to ask for help.

Building on this generic understanding of academic resilience, and on neurobiological understanding of affect as an integral part of cognition [4], we have built a pragmatic description of 'mathematical resilience' [1].

Originally we theorised mathematical resilience as having 4 factors:

- belief that brain capability can be grown;
- understanding of the personal value of mathematics;
- an understanding of how to work at mathematics;
- awareness of the support available from peers, other adults, ICT, internet, etc.

We have subsequently found it helpful to think of mathematical resilience as what is needed to stay, as long as possible and safely, in the 'growth zone'. To help explain what this means, we use a revised model of Vygotsky's 'zone of proximal development', or ZPD (see Fig.1).

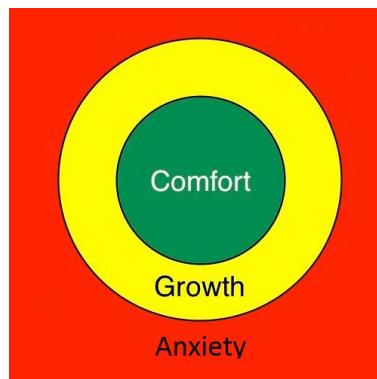


Figure 1: The growth zone model

The safe zone or 'comfort zone' encompasses everything the learner can already do independently. Cruising in the 'comfort zone' can build self-confidence, provide opportunity to practice and to develop automaticity, give reassurance and allow for recovery. The 'growth zone' is that zone immediately beyond what a person is able to do reliably, without aid or support. When in the growth zone, new learning happens. In the growth zone it should be made safe to make mistakes, go down dead-ends, experience some failure, require support, get stuck and find activity challenging and tiring. The learner needs to know in advance that being in the growth zone may trigger productive levels of adrenalin, which might develop feelings of excitement or mild anxiety. The learning environment needed is one of trust, courage, articulation, collaboration and persistence. Ideally, students will feel motivated and appropriately supported – and have opportunity – to enter their growth zone often.

The danger zone or 'anxiety zone' is where what is being asked of the learner is not within their reach, even with support. With increased exposure to such demands, the learner's level of stress increases and the brain begins 'fight, flight or freeze' routines. There is less or, in extremes, no useful learning taking place, and learners increasingly use maladaptive coping strategies of avoidance, helplessness or even paralysis.

We propose that positive mathematics experiences, together with a language of risk awareness and risk management can help learners to develop risk taking and risk management processes which then lead to mathematical growth. Learners need to experience the protective factors: connection, competence, opportunities for participation and contribution. This does not all need to happen within the mathematics lesson.

1.3 Developing coaches to support emergent mathematical resilience

A resilient stance towards mathematics can be engineered through a strategic and explicit focus on the culture of learning mathematics within both formal and informal learning environments. In the context of the current chronic shortage of teachers of mathematics, it seems to us that part of the solution lies in developing mathematical resilience outside the mathematics classroom in all adults and children. Our proposal for achieving this lies in developing 'coaches for mathematical resilience' who behave much like Heather in everyday life. Traditionally, a coach will support, respect, listen, be compassionate, validate, model resiliency, and refrain from judging, enabling a coachee to feel safe in taking risks in order to grow mathematical capability.

We envisage coaches for mathematical resilience helping learners to recognise for themselves when they are in their mathematical growth zone, and encouraging learners to value the challenges this brings and to manage the emotions involved. Coaches use a language that allows students to recognise and articulate what degree of challenge they are facing; encourage increasing independence and agency; model a strategy or model being part of a community of practice; know how to access help. Any adult, 'mathematical' or not, can support a learner of mathematics by understanding the zones and by encouraging explicitly the development of mathematical resilience.

The work described here is focused on developing coaches who work beside learners, helping them to think about and use resilient learning ideas when facing difficulties in mathematics. Coaches develop a culture of 'can do' mathematics which works to counter the prevalent culture of mathematics helplessness and mathematics anxiety in the general population when faced with mathematical ideas. The coaches are not required to *know the answer* but rather to develop the learners' ability to recognize options and actions that might yield an understanding of the mathematical ideas involved and thus lead to an answer.

2 PILOT COURSE

This paper discusses the outcomes of a pilot course designed to develop 'coaches for mathematical resilience'; the course ran from April to June 2013. The course recruited 11 participants who regularly work with apprentices, in a work-based environment who are required to learn and use mathematics as part of their on-going training. They became part of the course due to recognition of their own lack of knowledge about how to overcome deep seated antipathy to mathematics those who they work with and in most cases in themselves.

2.1 Course structure

The Coaching for Mathematical Resilience pilot course was designed and delivered by The University of Warwick and The Progression Trust, and was accredited by ASDAN. Challenges from the ASDAN Short Mathematics course were used as the focus for developing personal mathematical resilience. The Coaching course is designed with two levels: 1 Foundation Level in which learners work to develop their own Mathematical Resilience; and 2 Practitioner Level in which learners apply their resilience to working with and coaching their own learners for Mathematical Resilience. In this paper we discuss the outcome of level 1.

The Coaching for Mathematical Resilience Course combines two main features: the coaching skills and attitudes, which reflect the principles of developing resilience in learners, and the development of a personal 'can do' approach to mathematical challenges (see Fig. 2).

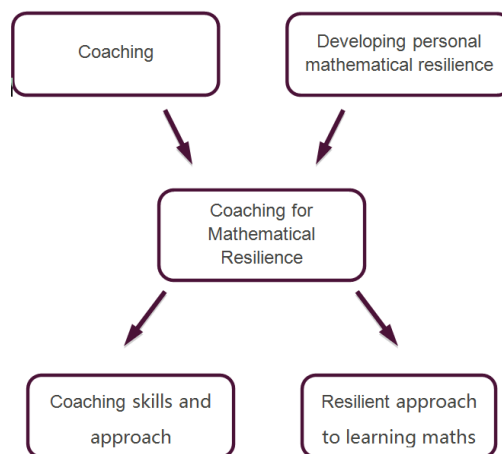


Figure 2: Two input elements and two output elements

The course consisted of ten half-day sessions in which coaching and mathematics were interwoven under the following headings: creating the learning community; developing awareness of what mathematics looks like in everyday life; developing mathematical resilience and coaching skills in the context of ASDAN Number; Money; Probability; Statistics; Mathematical Discovery; Algebra; Geometry; presentation of certificates and sharing images of mathematical resilience.

2.2 Significant ingredients

2.2.1 *Dual leadership*

The course structure models the essence of coaches not needing to know the mathematics. The expert coach focuses on techniques, skills and dynamics of coaching, and being mathematically resilient whilst not being a mathematics specialist. The mathematics expert focuses on providing engaging, accessible mathematical tasks to create the opportunity to undertake mathematical activity starting from where the participants are, and leading them into areas of risk-taking to achieve mathematical success. Two leaders were used in the pilot, to keep the two kinds of expertise clearly distinct.

The mathematical resilience model led to the additional significant elements described in the following sub-sections.

2.2.2 *Significant ingredient: Growth zone model*

For the growth model to be effective and for the participants to appreciate the significance of this model it was deemed important not only to introduce this model but for the participants to become aware of themselves undergoing their own zone experiences. The philosophy was, the participants would experience the zones and be safely supported by the coach and each other to overcome any panic and anxiety they experienced so they could then progress to understanding what their learners might experience and be able to support them with managing the affect aspects of learning mathematics,

2.2.3 *Significant ingredient: developing a community of practice*

The underlying theory is one of social constructivism; that many learners do better at mathematics if they learn in groups, with conjoint agency (ref), ie shared responsibility for each other's learning, explicitly shared responsibility for keeping each other safe when embarking on mathematical challenges, explicit trust, and inclusion. This was built into the course by starting with a session on hopes and fears, and growth zones, then collaboratively developing ground rules for subsequent sessions.

The ground rules developed by the participants were:

"Be honest if struggling; respect other people's feelings and current understanding; keep things said or done in the group to keep things safe; help each other and offer help; laugh with, not at; the outcome

is we all get there – we don't leave anyone behind; we act as a support network; things we say are temporary offerings; look after yourself; start from where we are; HAVE FUN!"

This emphasis on a supportive learning community, made explicit early on in the course, was intended to foster curiosity to replace fear, and to encourage the participants to take risks. The mathematics expert offered tasks that built on participants' innate and developed capacities for mathematics

We had envisioned that to build a community of practice would take time. As a precaution, seeking to ensure inclusion for all participants, no matter how anxious about mathematics, we planned the course over ten half-day sessions.

2.2.4 Significant ingredients: increasing awareness of use of maths in everyday life

One of the fundamental tasks in building a mathematical community of practice is to have a shared understanding of language because it is this that allows mathematical thoughts to be shared and explored [5]. Thus, using mathematical language within a learning community is an important part of developing mathematical resilience.

The use of specialised mathematical language is ultimately necessary to work effectively within a variety of mathematical communities of practice [6]. Often learners do not learn to use specialised mathematical vocabulary themselves in school and this can become a serious impediment to later inclusion and learning. A further benefit to using the conventionally accepted expressions of mathematics is that it is in using those expressions that a person is accorded the status of a possessor of mathematical knowledge [7]. In order to be inclusive, we have subsequently begun to describe specialised mathematical terminology as a mathematician's dialect.

To enable the participants to develop their own mathematical dialect, and their awareness of the use of mathematics in everyday life, we designed the course to build connections between the mathematician's 'dialect' and the dialect used by the participants in their everyday lives when thinking mathematically. Terms such as 'net' are used very specifically in the mathematics dialect; the idea of a two dimensional pattern for a three dimensional object is common in various everyday activities, but the term 'net' is often used to mean something very different.

We used familiar topics, such as preparing a meal and planning a journey, to explore participants' existing mathematical thinking and their dialect, introducing mathematician dialect as appropriate. We made connection between the mathematical term 'probability' and the term 'risk' as in risk-analysis.

We contend that using the notion of dialect undermines the notion that personal words are 'wrong', reduces the hegemony of mathematics teachers and increases the accessibility of mathematical terms.

2.2.5 Significant ingredients: interesting, engaging, challenging mathematical tasks

The mathematical tasks were carefully chosen to be accessible, open and student-centred. One example which was well received was four 4s. Participants were encouraged to collaborate inside and outside the sessions on completing a grid of numbers from 1 to 100 using just four fours and mathematical symbols. For example, $4 + 4 + 4/4 = 9$.

In the following section, we give the evaluation of the course from the participants using their own words.

3 INTERIM EVALUATION

Participants on the Coaching for Mathematical Resilience course were asked if they would take part in an evaluation at the end of the Foundation Level (level 1). Interviews of around 30 minutes each were conducted using Appreciative Inquiry methodology. Appreciative Inquiry uses an asset-based, story-telling approach to explore what has worked about learning and circumstances, rather than focusing on weaknesses; the aim of appreciative inquiry is to better understand what strengths exist that can be built on to maximise future impact. Interviews focused on 'high points' and 'special' moments as these are a signal for points at which participants were engaged, inspired or motivated. By understanding better what factors contributed to this moment, it is possible to identify the underlying attitudes, actions and environment that can be built on in future to improve engagement, innovation and motivation, and make them the norm rather than the exception.

3.1 High points of the course

Participants were asked to describe moments on the Coaching for Mathematical Resilience course when they were engaged in and excited about what was happening. The high points they identified were: using the Growth Zone model, the learning environment, specific mathematical tasks, and simply 'all of it'. The elements that made up the special moments were a combination of: having understood; having a sense of achievement; working together; enjoyment and excitement; being in a safe learning environment; receiving positive feedback.

Participants identified how they had been feeling at these moments that were special for them. At the start of the activity they had felt: anxious and panicky; confused and frustrated; empathy for their own learners; excited. They then moved on to feeling: enjoyment; motivated, empowered, engaged; proud; confident. Finally, they reported feeling: comfortable; safe; supported and part of a learning community; a sense of achievement.

Participants identified how other people had contributed to the success of these particular moments as coaches. They had: listened and taken a back seat; asked questions; developed confidence in others; given constructive feedback; shown respect and inclusion; calmed and reassured; made suggestions; used useful strategies; worked together, supported each other and shared.

Participants identified how they themselves had contributed to the success of these particular moments as coachees. They had: contributed specific strategies, questions and skills; listened; shown respect and flexibility; been interested, enthusiastic, confident and willing to have a go; been open and honest; given constructive feedback; shown commitment; worked together, shared and contributed different things.

3.2 Evidence of impact

Participants were asked to describe times outside of the Coaching for Mathematical Resilience course when they were engaged in and excited about what was happening.

Examples of the high points they identified were:

- feeling confident to support, and using coaching for mathematical resilience skills, in lessons with groups of learners;
- with individual learners, feeling confident to support, and using coaching for mathematical resilience skills;
- supporting learners preparing for mathematics tests and exams;
- explaining the course to family members;
- having mathematical curiosity and exploring mathematical resources.

Participants explained what had made these particular moments special for them. They described their trainees: developing confidence and a 'can do' attitude; feeling supported; succeeding and gaining a sense of achievement. Participants identified instances of managing being scared, being newly confident, comfortable and calm; feeling motivated to learn mathematics; enjoyment and fun; excitement; pleased and feeling good.

Participants identified how other people had contributed to the success of these particular moments. They cited examples of learners as equal partners, open to doing extra work, willing to try, passing their exams. They described positive feedback about their work as emergent coaches. They described other course members as enjoying the course, discussing it at work and supporting each other and their family members being interested.

Participants identified their own role as coaches as including: recognising and listening to learners' anxieties; using mathematical resilience skills with learners, colleagues and family; feeling confident to support learners; feeling motivated, enthusiastic and curious to learn mathematics. They saw their new skills as transferable into other aspects of their lives. They wanted us to emphasise that the course is about mathematical resilience, not mathematics.

4 DISCUSSION AND CONCLUSION

Particular parts of the Appreciative Inquiry methodology elicit specific insights about participants' wishes, intentions and values. The actual language used by the participants themselves is very important as it is the language that they use to express what they value.

There were six features of the course particularly valued by the participants. First, the learning environment was experienced as conducive to learning. This ensured that participants: felt safe; worked together as a collective and in communal activity; had fun and enjoyed the learning; experienced success and achievement. Second, they valued that the affective aspects of learning were attended to by giving participants opportunities to experience and to articulate their emotions in a safe way, and to identify strategies for managing emotions so that they could move from unproductive anxiety to productive learning. Third, the participants valued provision of mathematics tasks that they found to be challenging, fun, interesting and relevant. Fourth, they valued the opportunity to learn resilience skills. Fifth, they valued learning coaching skills and using tools and tactics applicable to the learning of mathematics, and sixth, they valued having time to reflect on their learning on the course.

These interim findings confirm our course design. The recommendations are that course designers and deliverers explicitly build these aspects into their delivery. Two tutors, one a maths education specialist and the other a coaching specialist, should collaborate in the delivery of the course to ensure that these aspects can be adequately addressed and integrated into delivery. Because time is needed to develop a community of practice, a course such as this cannot be short. The evidence from observations was that, by week three, the group was beginning to function effectively as a community of practice. The data confirms that, in order to become an effective coach, an individual first needs to develop their own personal mathematical resilience, by work through anxieties and negative stance towards mathematics in a safe and collaborative environment; they can then coach a learner to develop as a resilient learner of mathematics. An environment that enables an individual to become a mathematics resilience coach will need to expose participants to mathematical ideas; this will enable participants to consider and manage their own reactions to these ideas and to reflect on how to help someone else find the resources to overcome their own barriers to learning mathematics.

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