A case study addressing mathematics anxiety in an adult learner, drawing on mathematical resilience and self-determination theory

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We bring together Self-Determination Theory (SDT) and mathematical resilience (MR) to address mathematics anxiety. The focus of SDT on meeting basic psychological needs to enhance wellbeing and prevent harm provides grounding for much good practice in mathematics education, including work in MR. We illustrate this with the case of an adult learner. MR goes beyond what is currently proposed in SDT; we illustrate how MR tools can specifically facilitate learner emotion regulation, by developing mathematical learning competence, leading to greater wellbeing, learning, and a release from mathematics anxiety.

Keywords: mathematics anxiety; mathematical resilience; self-determination theory; mathematical learning competence.

Introduction

COVID-19 has highlighted the effects of anxiety and the issue of general well-being of young people. Many students have been adversely impacted by school shutdowns; for some, anxiety has dropped (Widnall, et al., 2020). Mathematics anxiety affects an estimated 30% of learners (OECD, 2013) – this is a wellbeing issue, and also has an adverse effect on the STEM pipeline.

We combine two theoretical frameworks: self-determination theory (SDT) (Ryan and Deci, 2017), a "mega-framework" which has been used for research in different development stages, contexts (including education) and cultures, and mathematical resilience (MR) (Lee & Johnston-Wilder, 2017), a "mini-framework" introduced in 2010 dealing specifically with mathematics anxiety. We seek to combine these frameworks, as we recognise the contribution that SDT can make to the issues with which MR is concerned (Mackrell & Johnston-Wilder, 2020). We illustrate, using a case study of an adult learner, how the two frameworks can work together in understanding and addressing mathematics anxiety.

Self-Determination Theory: basic psychological needs

The focus of SDT is on wellbeing. People are assumed to have agency and a natural growth tendency, facilitated or thwarted by the extent to which their basic psychological needs (BPNs) are met. There are observable, positive consequences for a person's wellbeing when needs are met, and significant harm, including anxiety, when needs are not met (Ryan and Deci, 2017). SDT identifies three basic psychological needs. Autonomy is ability to regulate actions in accordance with authentic interests and values; competence is feeling effective in interactions within important life contexts, with the ability to exercise, expand, and express capacities. Relatedness is feeling valued, connected, and belonging in social contexts. Students collaborating on tasks they enjoy and experience success with are likely to have all three needs met.

The case study: thwarting basic psychological needs

"Jackie" is a middle-aged tutor with engineering apprentices; she wished to address her "anxiety and avoidance, even hatred, towards maths". She had two sessions with Sue, talking about experiences of mathematics in the past, being introduced to the MR tools and doing some mathematics. In this section, we explore how the experiences of Jackie illustrate BPN needs being thwarted in the context of mathematics learning.

Autonomy Thwarting

Jackie experienced autonomy-thwarting through lack of choice about setting (she had no opportunity to do mathematics O level, a crucial qualification at age 16 for many career choices). She also experienced finding mathematics personally meaningless, in particular not understanding the point of algebra, or why mathematics mattered.

Competence Thwarting

Jackie perceived herself a failure at mathematics: "I just remember consistently getting it wrong and not knowing why". In commercial maths, she got "a really bad grade … one of my lowest grades" and did not see any hope for herself: "some people are not any good at maths and never will be." Explanations did not make sense: "I was feeling double bad about not understanding what they were saying as well as getting the maths wrong", and mathematics involved incomprehensible artefacts: "I was terrified of that slide rule. I never ever understood how that worked."

Relatedness Thwarting

Jackie recalled feeling comfortable and valued in English lessons, but not in mathematics lessons. She perceived that no-one had ever taken time with her individually. She was publicly told that she got it wrong and felt too embarrassed to ask for what she wanted, which was an idea of why mathematics mattered.

Need-supportive and need-thwarting environments

The most important aspect of a need-supportive environment according to SDT is autonomy support, which underpins all of the BPNs. This involves: enabling, actively encouraging, and valuing meaningful choices; identifying, developing and supporting a person's interests; valuing their thoughts and feelings; encouraging self-regulation; and taking on their frame of reference (Ryan & Deci, 2017).

In contrast, a need-thwarting environment involves controlling or intruding on students, giving meaningless or uninteresting tasks, disrespecting and suppressing criticism as acting against the need for autonomy. Students may experience pressuring tactics such as punishment or shouting, hear phrases such as "you have to" (Stroet, 2013). Much of mathematics education resource concerns ways in which maths classrooms can be need-supportive rather than need-thwarting. Some examples are Realistic Maths Education (https://rme.org.uk/), NCETM working groups (for example, Lee, 2016; Johnston-Wilder & Moreton, 2018; Bowland Maths, n.d.).

Addressing mathematics anxiety: introducing mathematical resilience

Changes to a learning environment may not, however, be enough for an adult learner such as Jackie; more specific interventions may be necessary. Although there are

some promising directions in SDT involving e.g. mindfulness and emotion management, there are as yet no specific interventions in the case of anxiety.

We hence turn to mathematical resilience (MR), defined as "maintaining self-efficacy in the face of personal or social threat to mathematical well-being" (Johnston-Wilder & Lee, 2019, p. 3). Three constructs used in MR, personal value of mathematics, growth mindset, and community, align well with the SDT needs for autonomy, competence, and relatedness, and the general teaching approach of MR aligns with need-supportive teaching. A fourth construct, recognition of the value of struggle and the ability to persevere in learning situations, connects with autonomy and competence; the key to struggle is ability to manage anxiety when it arises. MR has introduced a number of specific tools to enable such anxiety management; these tools were introduced to Jackie in the context of doing some simple mathematics.

Hand model of the brain

This model, based on Siegel (2010), was introduced to help Jackie reframe her reported sense of being 'stupid' at mathematics and enable her to call a pause whenever needed. Sue described how the wrist in the model represents the brain stem, and the thumb the "primitive part of the brain", shared with all animals, which Sue called the "alarm system". She explained that the back of the hand represents the cortex, which is shared with most mammals, and the fingernails represent the prefrontal cortex, which is where complex human thinking, involved in reading, writing, and arithmetic, takes place.

Sue connected the folded hand with Jackie's reported experience of nervousness; by telling herself: "it's okay, it'll be fine, Sue seems kind." Jackie managed to arrive at the session in a state of challenge. Sue suggested that Jackie's cognition had regulated her alarm response; Sue contrasted this experience with a perceived threat situation in which the alarm system is not regulated, and the brain is effectively "trying to save your life" (represented by the open hand). Sue noted that the system does not distinguish between physical threat and social threat, manifesting as feelings of shame and humiliation; anything that results in isolation from the immediate social group can be experienced as a fundamental threat to existence.

Relaxation response

Secondly, Sue introduced the relaxation response (Benson, 2000). Triggering this response is a technique used in mindfulness meditation. The aim is to bring focus back to the now, taking a "step back" from overwhelming feelings of panic. Sue said:

> If you're a diver, then you need to know how to trigger that [response] because if you panic underwater, you use up too much oxygen and then you die, so divers learn explicitly to reduce their heart rate, to reduce the oxygen [use].
>
> If you breathe in for five and out for seven, you are overriding the alarm because you're telling the brain [to activate] the parasympathetic nervous system – the rest-and-digest system.

Growth zone model

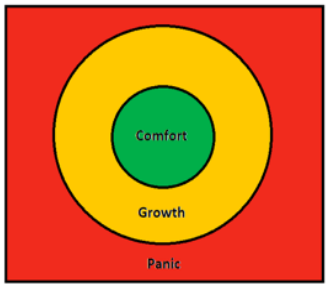

Figure 1 A growth zone diagram (based on Lee and Johnston-Wilder, 2017)

The third tool Sue used gives a pictorial representation of ways in which a situation may be experienced. A diagram like the one in Figure 1 was created by Jackie and Sue working together as Sue explained the idea. Sue said:

> The third tool pulls it together ... [Sue draws a circle, Jackie colours it.] Everybody talks about this as the comfort zone, and sometimes you could say: "I'm going to step outside my comfort zone."
>
> What we don't talk about very often, and yet it's in the literature, is that there are two spaces outside the comfort zone. [Drawing a ring around the green circle.] There's the growth zone, where you find everything challenging and exciting and slightly unnerving, but you know that you are learning and it's an experience, although it's scary and [you might feel] nervous. …
>
> [Indicating the outside space.] There's the red zone - panic … threat.
>
> When you first go into a maths environment, your brain perceives a threat, so you go straight into red … with the relaxation response, you learn to get out either back to green or into orange, and then you can tackle any maths problem [in time].

After introducing the three tools, Sue talked to Jackie about a multiplication table and noticed, from Jackie's non-verbal response, that Jackie was feeling more anxious. Sue deliberately stopped at this point and encouraged Jackie to use the hand model of the brain to indicate she needed a pause, stressing that she (Sue) would stop until Jackie gave her permission to carry on. Jackie expressed how frightening she found numbers. When Sue asked if it was okay to draw the tiles in a bathroom instead, Jackie indicated that this was alright, because she could visualize this, and Sue used this model to help Jackie create a multiplication table by counting.

Jackie's responses

In the first session, after the introduction of the first two tools, Sue asked Jackie how she was feeling. Jackie responded:

> I'm feeling much more relaxed and I feel as though I'm almost addressing something that was very unfair many years ago [laughs], because if I'd been open to this, had support with this at that time, my life could have been very different because I could have been embracing maths.

At the beginning of the second session, Jackie commented:

> I don't feel embarrassed any more about my struggles with maths, because you made it sound completely ok, and that actually it's not really necessarily my fault. It's the fault of the system... it's made me feel more positive about it. And other things I struggle with, like the IT and things like that, it's made me feel similarly about that … I wouldn't say the anxiety has gone, because I still [feel anxious],

> when I see the little *x*'s … But the embarrassment has gone. And this is a place of learning, and I want to learn.

She also reported wanting to complete the multiplication table that she had started with Sue in the first session:

> I felt I wanted to complete that when I got home. And I couldn't actually believe that I was wanting to complete something [in maths] … who is this person? But I think, because I understood it and I knew I could do it, I wanted to do it. … those things haven't been in maths for me before.

Jackie also reflected specifically on the three tools. To the hand model, Jackie responded: "That's transformational." During the second session, Jackie said:

> [The hand model] was very powerful, because I felt that it was absolutely ok for me to put my hand up at any point. I wasn't playing a game, where I was thinking I can't possibly put my hand up now and pretending to understand it. I was able to put my hand up, and that made a big difference, because that gave me the confidence to complete this. And I thought, I can connect with something, and that's completely ok, and that's only going to get better. So, I did like that. Because that was about me and how I felt, not how I thought I should feel.

Jackie recognized the relaxation response from her generic use of mindfulness, but, importantly, would not have thought to apply it to her issues with mathematics.

> I did spend quite a bit of time thinking about [the relaxation response]. Breathing helps me ... You know, you are still alive and if the worst comes to the worst, you can just remove yourself physically from where you are, if you absolutely have to.

Jackie then talked about watching a competition in which someone who was not comfortable with a task took a minute out:

> … then he came back, and he said, I'm just going to do what I can. And he asked somebody for some help, and they came and helped him, so he knew where to start. … I could identify with that, and I thought, yeah, that's what it is all about, really, isn't it? Just saying I need a bit of time out here.

About the growth zone model Jackie said:

> It made sense to me as well, because I'd thought quite a lot about the sense of wanting to be in the second zone. Because that's how you develop as a person, not just with maths, but with everything in life. And I think I'm probably quite an anxious person anyway, more than I originally thought. And so, to be in that safe but stretchy zone is good. But then, I can see how, with maths and some things, I tend to go straight from the safe zone to the red zone. There's no in-between. And I think, when I do that, that's when I back off and remove myself.

The intervention clearly changed Jackie's relationship to mathematics. She reported ceasing to feel embarrassed; although still anxious, she was beginning to view mathematics as a challenge she could deal with, rather than as a threat.

Discussion

We ascribe the impact of the MR intervention to Jackie's increased understanding of her emotional response to threat (the hand model); and specific tools to manage that experience (the breathing response) and to reinterpret experience (the growth zone model). We have previously highlighted the importance of "mathematical learning competence" (Mackrell and Johnston-Wilder, 2020), which is defined as "the competence that enables learners to remain in the growth zone, the zone of optimal challenge, in which learning is greatest, involving awareness of emotions, tools,

support, and strategies" (ibid). We suggest that such competence is integral to students' basic psychological needs in the context of learning mathematics.

Conclusion

We have discussed how SDT, concerned with meeting basic psychological needs in a learning environment to promote wellbeing and growth, aligns with MR, and how MR supplements SDT by giving specific tools to manage anxiety. We note the importance of introducing such tools in a mathematics learning environment in order to enable learners to develop mathematical learning competence. We suggest that an explicit focus on developing mathematical learning competence through being introduced to such tools will contribute to much-needed greater participation in STEM.

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