People are afraid of looking incompetent: How can we stop fear of mathematics from holding us back?

Building resilient learners – Research in andragogy of teaching mathematics

Masha (Maria) Apostolidu[1] and Sue Johnston-Wilder[2]

[1]Lewisham College, London, UK
[2]Warwick University, Coventry, UK

Abstract
Mathematics anxiety is a prevalent problem: about a third of the students globally report fear of mathematics. Recent studies suggest that math anxiety might be negatively related to individuals' ability to make advantageous choices and decisions beyond classrooms. There is a growing need for simple, comprehensive, practical approaches available to educators, carers and learners to address this and overcome emotional barriers to learning mathematics.
This paper, discusses the results of a qualitative small-scale study implementing 'The Toolkit', a new approach introduced by Johnston-Wilder at al. (2020). The research underpinning The Toolkit is reviewed, the notion of psychological safety introduced and the process of the intervention is described.
The results report reduced levels of anxiety and development of positivity towards mathematics. The key themes highlight the importance of addressing emotional aspects of learning mathematics in the classroom. All participants have rated the Toolkit as 'extremely useful' and would advise it as a practical strategy to anyone having mathematics anxiety. This approach warrants further research to properly establish its efficacy in different contexts.

Key words: affective barriers, mathematics anxiety, mathematical resilience, the Toolkit, psychological safety

Introduction

Poor numeracy is widespread in the UK. Government statistics suggest that 17 million adults in England - half of the working-age population - have everyday mathematics skills roughly equivalent to those expected of a primary school child (Skills for Life Survey, 2012). Poor numeracy affects work productivity, people's income, health and wellbeing. Although many efforts are in place to improve numeracy in the UK (How Can I Improve My Maths Skills? How the Multiply Programme Supports Adult Learners - the Education Hub, n.d.), efforts often focus on the role of the cognitive factors (such as increasing maths requirements, introducing novel teaching strategies and increasing educational standards), while the importance of the emotional and social factors in improving numeracy and maths achievement is mainly overlooked (McLeod, 1992).

Improving mathematics curriculum content addresses only part of this issue; we also need to address emotional factors known to affect maths learning, performance and interest in pursuing careers that require good numeracy skills (Beilock & Maloney, 2015). In order to address emotional aspect, mathematics educators and learners need a simple and comprehensive approach that can be integrated into the existing cognitive

framework of learning mathematics; such an approach will remediate factors negatively influencing mathematical performance of maths-anxious individuals (Beilock & Chang, 2016).

Further education (FE) colleges in the UK are facing the challenges of delivering mathematics as a compulsory subject for those that have previously failed to achieve grade 4 in GCSE mathematics. Most commonly reported issues are low levels of motivation and engagement and affective difficulties such as low confidence and anxiety (Noyes & Dalby, 2020). Teachers often comment on the need to reinforce attendance of students who previously experienced failure with mathematics. Seligman (2007) considered that repeated exposure to stress can lead to avoiding behaviour in order to escape a repeat psychological suffering. Johnston-Wilder et al. (2013) propose that it is not the mathematics as such but the accumulating effect of the repeat negative experiences that can result in avoidance as a form of psychological protection from further harm.

Johnston-Wilder and Lee (2010) defined the construct 'mathematical resilience' as a framework to counteract mathematics anxiety and mathematics helplessness. Mathematics resilience (Fig. 1) involves four factors: belief in growth, personal value of mathematics, need for effort and struggle to achieve learning, and accessing available support (Johnston-Wilder et al., 2016). Building on the construct of mathematical resilience, Johnston-Wilder at al. (2020a, p.1) introduced the Mathematical Resilience Toolkit which combines four tools addressing mathematics anxiety, psychological safeguarding and effective response to challenge and threat in the context of learning mathematics.

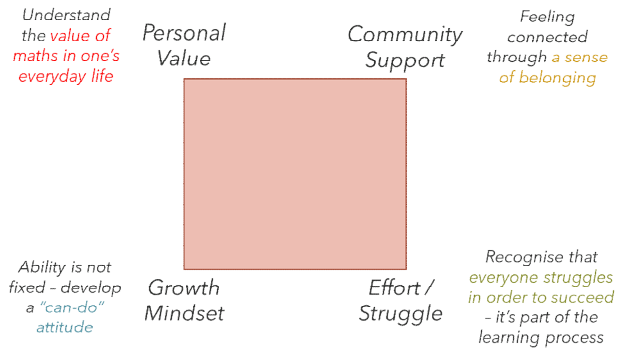

Figure 1 Mathematical Resilience

Whilst general resilience was investigated extensively in the past (Luthar 2006; Masten et al. 1990; Wagnild and Young 1993), only few studies examined resilience in academic settings and specifically resilience in the mathematics studies (Johnston-Wilder and Lee 2010; Kooken et al. 2016; Ricketts et al. 2017).

In this study, we explore the effectiveness and accessibility of the Toolkit for building resilience, reducing mathematics anxiety and increasing effectiveness of learning in the context of adult learners in a Further Education college in London.

Methodology

Approach

This is a small-scale action research study undertaken with a group of 8 pre-GCSE mature students, in FE college in London. Two researchers (Sue and Masha) collaborated closely throughout the whole process of the study, including data presentation, interpretation and collaboration on the structure and timeline of the intervention. One of the researchers (Masha) was also the mathematics teacher of this class. The originality of this approach is that the effectiveness of the intervention is examined from more than one perspective, providing a more holistic grasp of the issue, as data is gathered from all parties related to the applications, such as students, teacher, academic researcher, and wider community.

Intervention components

Listening to prior experience

In the first session, after introductions and procedure agreements, each participant was invited to share their personal maths story, i.e. good and bad examples, and their coping strategies. All participants identified negative past experience from learning mathematics; some stories described painful emotional experiences, i.e. “In class all other students understood the topic, and I would still not understand. It made me very sad and discouraged” and physiological elements, i.e. ‘heart beating very fast’, ‘feeling dizzy’. Two participants remembered being physically punished by their teachers for not understanding and would miss their classes to avoid punishment and shame.

Psychological education

The session following maths stories, involved learners understanding mathematical anxiety and the role of the brain and emotions in learning. The learners were presented with examples of connection between negative feelings about mathematics and low confidence and explored the effect of safety on learning. All learners confirmed that MA was a new concept and that they were not aware that fear of mathematics can disrupt their learning by overloading their working memory and causing mathematics avoiding behaviours (Dowker et al., 2016). Many learners had established beliefs in their inherent inability to learn mathematics.

Visual representations were used to summarise recent neuroscience research so that students can understand how anxiety affects the brain and why maths avoidance is common. The usage of brain images makes psychological arguments more convincing (McCabe and Castel, 2008), which strengthens the notion that the students’ anxieties are due to neurological factors, rather than a notion that they “can’t do maths”.

The Toolkit

The Toolkit comprises four tools (Fig 2): the hand model of the brain (HMB; Siegel, 2010), the relaxation response (RR; Benson, 2000) and the growth zone model (GZM; Johnston-Wilder et al., 2020b, p.10) and The Ladder model (Bruner, 1966). Desensitisation and gradual exposure to anxiety triggers (Petronzi et al., 2021) were integrated into maths lessons and students were encouraged to practise managing anxiety and developing persistence outside the classroom.

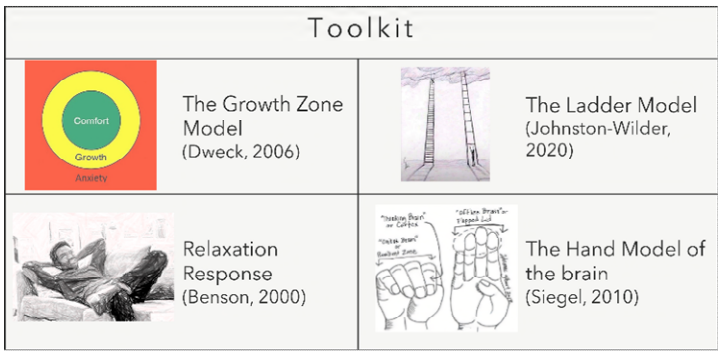

Figure 2 The Toolkit

Data collection

The qualitative data was collected through different means: field notes during classes, semi-structured individual or small group interviews, students' mathematics stories, and two surveys assessing mathematical wellbeing and motivation. The quantitative data included a 2-part questionnaire (confidence and anxiety), the Betz (1978) Mathematics Anxiety Scale (BMAS) and the Mathematical Resilience Scale (MRS) (Kooken et al., 2013), administered at the start (Assessment 1) and then repeated after 5 months of the intervention (Assessment 2). We concluded all observations and interviews in June 2022.

Results

Quantitative

Item responses in the Betz Maths Anxiety Scale were obtained on a 5-point Likert scale; responses ranged from 1 (strongly disagree) to 5 (strongly agree). Half the items measured confidence (Fig. 3) while the other half measured MA (Fig. 4).
The mean scores of the MAS at the first and second surveys were compared and showed 2 out of 8 improved scores in confidence and positivity towards their own maths progress.

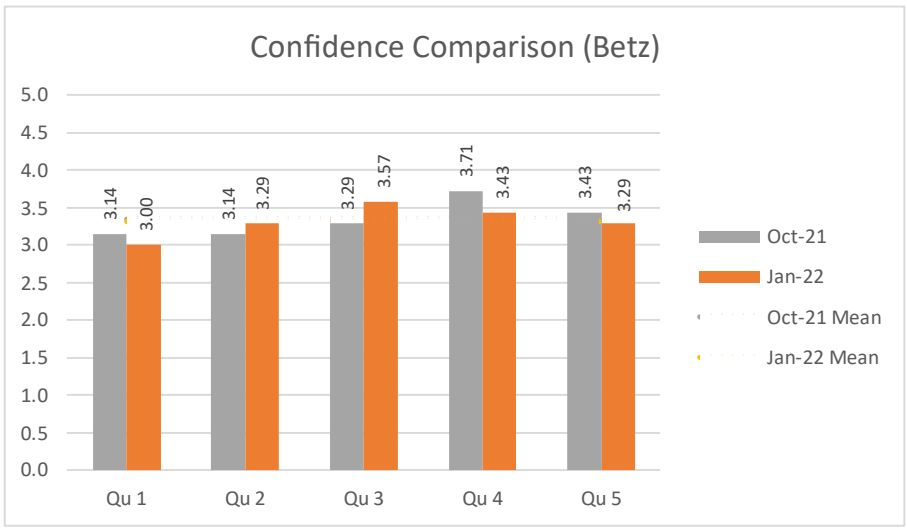

Figure 3 Confidence scores comparison

The mean scores of MA showed that 5 out of 8 participants had reduced scores in mathematics anxiety (Fig. 2) with the average decrease in MA of 0.09% in the second assessment in January 2022. However, the sample size was too small for making statistical inferences based on the quantitative data as small sample size does not allow for generalisation.

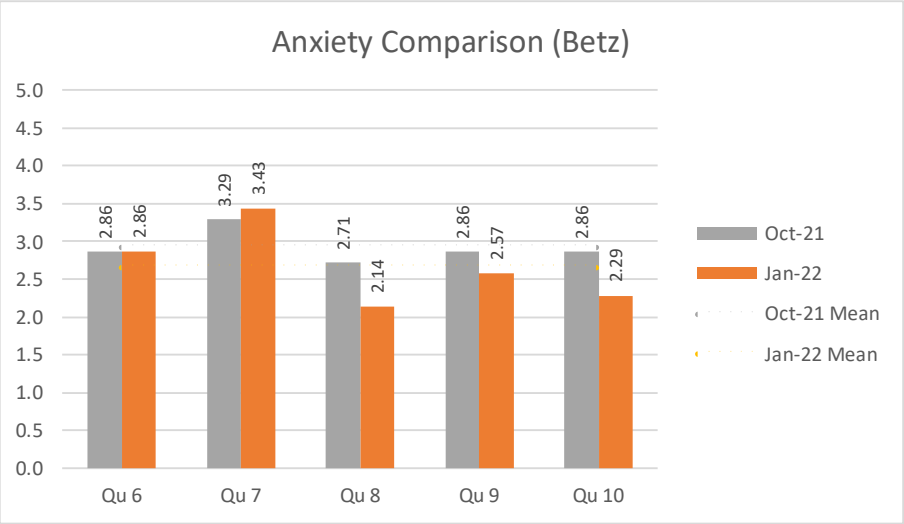

Figure 4 Maths Anxiety comparison

Qualitative

Braun and Clarke's thematic analysis (Braun & Clarke, 2006) was conducted to analyse qualitative data. Four key themes reflecting students' experience of the intervention, emerged from the thematic analysis: (1) role of the students (positive and negative self-appraisal), (2) role of emotions (fear prevents and safety promotes learning), curriculum (pace faster negative, slower positive impact on learning), (3) the role of curriculum in cognitive overload, (4) role of teacher. Each theme was subdivided into subthemes that reflected increase and decrease in resilience in the context of the intervention addressing mathematics anxiety (Fig 5)

Decrease in resilience Subthemes	Themes	Increase in resilience Subthemes
Negative view of challenge Giving up early Fixed mindset	Theme 1: Students	Value of challenge Deliberate effort Growth mindset
Fear and danger Negative about future	Theme 2: Emotions	Feeling safe Positive about future
Fast pace High curricular content Lack of support	Theme 3: Curriculum	Slower pace Less content at a time Varied support
Criticism Strict Poor teaching	Theme 4: Teacher	Kind Open to listening Good teaching

Internal

External

Figure 5 Themes and subthemes

All subthemes that indicated increased resilience were grouped together and coloured green, while those with decreased resilience were grouped together and coloured orange. Notably, we arranged the themes and their associated subthemes from internal to external to reflect the relationships and interactions between them.

Role of the students

When asked to evaluate the tools in the Toolkit most of the students made statements about the positive impact that Growth Zone and ladder models had on their beliefs about the role of learners in the learning process, and specifically developing self-efficacy in learning mathematics. They commented that they avoided challenge as a negative aspect of learning, believed that mathematical ability cannot be developed and felt helpless and hopeless in the face of challenge. The GZM provided the students with a model of barriers and opportunities for overcoming those, which they can use independently to understand their current learning mode and plan how to move to the next level. They also reported feeling more in control over own progress and used it to remind themselves that growth is possible. One of them said:

> "Now, I use Growth model at work, it helps me to come out of the comfort zone and strive for more with confidence. I even share it with my colleagues, when they go for promotions" (Mathilde)

The ladder tool used to remind them of gaps in knowledge and need to seek a specific support, the students evaluated it as a useful tool encouraging them to break down difficult questions into manageable tasks.
They concluded that having those tools gave them a set of "go to" strategies in the face of difficulties of maths, which had a positive impact of their confidence to have an active say in maths learning.

Role of emotions
Students expressed that their repetitive failure and apparent lack of ability increased feelings of fear and hopelessness to achieve a required pass grade for a vocational qualification or a degree. In response to that they opted for career choices reflective of those attitudes and often opted for low paid and low skilled jobs. Challenge corresponded with fear, defeat and low self-esteem followed by avoidant behaviour. When asked about their feedback on psychological safety and discussions about the impact of emotions on learning, they admitted that speaking about emotions in maths lesson was a new experience:

> "Talking about how I feel in maths class seemed very unusual way to learn maths. I thought to give it a go and to my surprise it helped me learn!"

The learners valued the Toolkit highly as a practical strategy for addressing fear and hopelessness.

> "I used to see mixed up numbers in maths problems and felt really stupid. I am not stupid, my brain can' t learn when I am scared" (Anthony)

The GZM allowed students to distinguish between the range of emotions from nervousness to fear and to communicate those emotions without feeling stupid.

> "When I am stuck doing MathsWatch at home, I can ask myself - what zone I am in, and when I am in the RED, I know that I am stressed, I need to relax, do something else and then come back to my task. I often can do my tasks very well after that as I start thinking clearly" (Seye)

When asked about their view on relaxation response and micro-mindfulness, the students commented that was a refreshing break 'like a reset' when they felt overwhelmed by mathematical rules and numbers. They commented that fear of failure and shame negatively impacted their mathematical abilities and positive affirmations encouraged feelings of hope in own progress in mathematics.

Role of the curriculum

When asked about the elements of learning that had negative impact on their confidence and safety feelings many students associated those with fast pace of going through curriculum, high saturation of content and hopelessness in case of falling behind due to fast pace.

One participant said:

> "it feels like you are running fast but teacher is moving even faster. So that your fast is never fast enough in maths"

Ther participants expressed the feelings of 'left behind' when everyone else moved on, they used to believe there is something wrong with them as everyone one else seemed getting on with the pace which prevented them from reaching out for help.

> "I always was scared of being behind and not catching up with other students. It made it only worse. This year was different because I knew I can always reach out for help"

Role of the teacher

The students noted that teacher's role in facilitating the intervention during maths lessons was very important. The students found it valuable that the teacher came across with empathy rather than critical and judgemental approach. They added that teacher was sensitive to their feelings, fears and worries and they felt that teacher considered their emotional difficulties with maths in lesson planning. Theu felt validated and safe to continue to open up and speak about their experience with the teacher. Other positive comments included organised resources in most convenient for learners way and multiple ways of conveying mathematical ideas. They expressed that support was explicit and they felt comfortable asking for help.

> "I always was scared of being behind and not catching up with other students. It made it only worse. This year was different because I knew I can always reach out for help" (Ariana)

Discussion and Conclusion

This study was first of its kind to address barriers to learning mathematics by embedding a set of tools (Johnston-Wilder et al. 2020) for mathematical resilience in mathematics classroom. A unique collaboration between one of the authors of mathematical resilience, Sue Johnston-Wilder, and mathematics teacher, brought the experiment into a real classroom by implementing psychological safety as a core teaching value and constructing mathematics delivery around the value of resilience, growth and safety (Johnston-Wilder & Marshall, 2017).. The teacher had high intrinsic motivation to extend teaching mathematics beyond standard cognitive methods of delivery and engage in practitioner research of emotional factors in learning.

Two-semester long intervention was conducted with a group of learners and results were analysed over the length of the intervention to examine the effect in the context of regular classroom teaching. The results suggest that the participants reported lower maths anxiety scores. The qualitative data conveyed a positive shift in students' attitudes towards challenge and struggle as necessary components of learning. Students communicated that the tools were easy to use outside of class and reported their

application in work-related contexts. They quoted that positive affirmations, relaxation and distraction strategies helped them manage anxiety and fear of failure during independent work and during assessments. It has been noted that all students in class attempted and completed homework and were actively seeking support from classroom community and online resources; they shared feelings of empowerment and confidence in overcoming own barriers and failures.

It is worth noting that one of the themes highlighted the role of teacher's empathy and teaching skills. This intervention calls to explore further implementation of the Toolkit with other practitioners in similar settings to explore the effect of the teacher in developing mathematical resilience and the effectiveness of the tools with different practitioners.

The possible explanation of small effect in quantitative data might be the small sample size and the interpretation of the questions' language, and in future interventions it could be modified to accommodate specific audience.

This pilot research was conducted to determine if the intervention was effective on a smaller scale before replication and expansion to other courses. The replication of the study with larger sample size is recommended to increase power and social validity.

Student retention and achievement on mathematics courses is a crucial goal in further education institutions and it significantly predicts sustainability and success of further education sector. Notably, mathematics anxiety and avoidance are powerful psychological barriers affecting many students' vocational performance in FE (Tobias, 1991), which warrants the need for further research of the mechanisms that generate those barriers and the interventions that can be easily accessible to students and educators. (Lyons&Beilock, 2013)

References

Bandura, A. (1995). Self-efficacy in changing societies. Cambridge: Cambridge University Press.

Beilock, S. L. Gunderson, E. A. Ramirez, G. and Levine, S. C. (2010). "Female teachers' math anxiety affects girls' math achievement", Proceedings of the National Academy of Sciences, 107(5), pp. 1860–1863.

Benson, H. (2000). The Relaxation Response. New York: Avon Books

Betz, N. (1978) 'Prevalence, distribution, and correlates of math anxiety in college students.' Journal of Counseling Psychology, 25(5), 441–48.

Braun V, Clarke V. Using thematic analysis in psychology. Qual Res Psychol. 2006;3(2):77–101.

Chang, H., & Beilock, S. L. (2016). The math anxiety-math performance link and its relation to individual and environmental factors: a review of current behavioral and psychophysiological research. Current Opinion in Behavioral Sciences, 10, 33–38. https://doi.org/10.1016/j.cobeha.2016.04.011

Cousins, S., Johnston-Wilder, S., & Baker, J. (2019. Mathematics: A Place of Living Kindness and Resilience-Building. Journal of the Canadian Association for Curriculum Studies, 17, 111-126

Dowker, A., Sarkar, A., & Looi, C. Y. (2016). Mathematics Anxiety: What Have We Learned in 60 Years? Frontiers in Psychology, 7, Article 508. https://doi.org/10.3389/fpsyg.2016.0050 8

Dweck, C. S. (2006). Mindset: The New Psychology of Success. New York: Ballantine Books.

Fiorella, L., Yoon, S.Y., Atit, K. et al. (2021). Validation of the Mathematics Motivation Questionnaire (MMQ) for secondary school students. IJ STEM d 8, 52https://doi.org/10.1186/s40594-021-00307-x

How can I improve my maths skills? How the Multiply programme supports adult learners - The Education Hub. (n.d.). Educationhub.blog.gov.uk. Retrieved May 30, 2022, from https://educationhub.blog.gov.uk/2022/05/18/how-can-i-improve-my-maths-skills-how-the-multiply-programme-supports-adult-learners/

Johnston-Wilder, Sue and Marshall, Ellen (2017) Overcoming affective barriers to mathematical learning in practice. In: 2017 IMA CETL-MSOR , Birmingham, 10-12 Jul 2017 (Submitted)

Johnston-Wilder, S. and Lee, C. (2010). Mathematical Resilience. Mathematics Teaching. 218, pp. 38–41.

Johnston-Wilder, S., Lee, C. , Brindley, J. and Garton E. (2015). Developing Mathematical Resilience in School Students who have experienced repeated failure. In Proceedings of 8th International Conference of Education, Research and Innovation, Seville, Spain.

Johnston-Wilder, S., Brindley, J. and Dent, P. (2014). A survey of Mathematics Anxiety and Mathematical Resilience among existing apprentices. London: The Gatsby Foundation.

Johnston-Wilder, S., Pardoe, S., Almehrz, H., Evans, B., Marsh, J. and Richards, S. (2016) Developing Teaching for Mathematical Resilience in Further Education, 9th International Conference of Education, Research and Innovation, ICERI 2016, Seville (SPAIN), 14-16 November, 2016.

Johnston-Wilder, S. , Baker, J. , McCracken, A. and Msimanga, A. (2020) A Toolkit for Teachers and Learners, Parents, Carers and Support Staff: Improving Mathematical Safeguarding and Building Resilience to Increase Effectiveness of Teaching and Learning Mathematics. Creative Education, 11, 1418-1441. https://doi.org/10.4236/ce.2020.118104.

Kooken, J., Welsh, M., McCoach, D., Johnston-Wilder, S., Lee, C. (2013). Measuring Mathematical Resilience: An application of the construct of resilience to the study of mathematics. Paper presented at national conference of the American Educational Research Association, San Francisco, CA.

Lee, C., Johnston-Wilder, S. (2013). Learning mathematics—letting the pupils have their say. Educ Stud Math 83, 163–180 https://doi.org/10.1007/s10649-012-9445-3education

Luthar, SS. Resilience in development: A synthesis of research across five decades. In: Cicchetti, D.; Cohen, DJ., editors. Developmental Psychopathology: Risk, disorder, and adaptation. Wiley; New York: 2006. p. 740-795.

Lyons, I. M., & Beilock, S. L. (2012). Mathematics anxiety: separating the math from the anxiety. Cerebral cortex (New York, N.Y. : 1991), 22(9), 2102–2110. https://doi.org/10.1093/cercor/bhr289

Masten, A.S., Best, K.M. and Garmezy, N. (1990) Resilience and development: Contributions from the study of children who overcome adversity. Development and Psychopathology, 2, 425-444. doi:10.1017/S0954579400005812

McCabe, D.P. and Castel, A.D., 2007. Seeing is believing: The effect of brain images on judgements of scientific reasoning. Cognition, 10(7), pp. 343–352.

McLeod, D. B. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grouws (Ed.), Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics (pp. 575–596). Macmillan Publishing Co, Inc.

Noyes, A., & Dalby, D. (2020). Mathematics in Further Education Colleges Final Report. https://www.nuffieldfoundation.org/wp-content/uploads/2019/11/Mathematics-in-Further-Education-Colleges-final-report.pdf

Ofsted. (2012, May 22). Every pupil needs a good mathematics education. Retrieved June 6, 2022, from https://www.gov.uk/government/news/every-pupil-needs-a-good-mathematics

Pekrun, R., n.d. *Emotions and learning*. IBE/2014/ST/EP24 http://www.iaoed.org

Peterson, C., Ruch, W., Beermann, U., Park, N., & Seligman, M. E. P. (2007). Strengths of character, orientations to happiness, and life satisfaction. The Journal of Positive Psychology, 2(3), 149–156. https://doi.org/10.1080/17439760701228938

Petronzi, Dominic & Hunt, Thomas & Sheffield, David. (2021). Interventions to Address Mathematics Anxiety: an Overview and Recommendations. In S. Kiray & E. Tomevska-Ilievska, (Eds.), Current Studies in Educational Disciplines 2021 (pp.169-194). ISRES Publishing

Ricketts, S.N., Engelhard, G., & Chang, M. (2017). Development and Validation of a Scale to Measure Academic Resilience in Mathematics. *European Journal of Psychological Assessment, 33*, 79–86.

Ryan, R.M. and Deci, E.L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. Contemporary Educational Psychology. 25, pp. 54–67. https://doi.org/10.1006/ceps.1999.1020

Siegel, D. (2012) Dr Daniel Siegel presenting a Hand Model of the Brain. Accessed via https://www.youtube.com/watch?v=gm9CIJ74Oxw (28 May 2017)

Tobias, S. (1991). Math Mental Health. College Teaching, 39(3), 91–93. https://doi.org/10.1080/87567555.1991.10532434

Wagnild, G. M., & Young, H. M. (1993). Development and psychometric evaluation of the Resilience Scale. Journal of Nursing Measurement, 1, 165-178.