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Math anxiety and math resilience in research and education in a world of diversity

Lęk przed matematyką i rezyliencja matematyczna w badaniach i edukacji w świecie różnorodności

Abstract: The aim of the study is to present math anxiety and math resilience as research categories worth exploring in contemporary educational research targeted at increasing the effectiveness of the educational process. The article aims to present the universal nature of math anxiety and math resilience, the occurrence of which is relatively independent of the specific nature of the education system. Understanding the mechanisms of math anxiety can help alleviate its various types, while disseminating knowledge about math resilience can be used to strengthen students' mental resilience to various difficult situations, not only those related to mathematics.

Keywords: math anxiety, math resilience, education, diversity.

Introduction

The modern world is full of diversity and changes that require the development of adaptive skills not only from adults, but also from children. Drawing attention to the phenomenon of resilience results from the need for its development and presence in children growing up in the conditions of the Western culture, easy to live in terms of availability of goods and services, but difficult due to global threats to fundamental values (health, safety, peace) and the rush of life, limiting the stable development of emotional and social competences.

The identification of criteria for differentiating resilience and the characterization of its types indicate the gradual expansion of the scope of knowledge about this mental and emotional process. This happens as a outcome of undertaking specific studies, resulting in turn from the needs of life and field practice, related to a large number of difficult and frustrating events that occur in everyday life in numerous areas of activity. The research results indicate the social importance of resilience in contemporary times of instability and the need to shape it from an early stage of development, regardless of the location of residence and education.

The aim of the study is to attempt to present the universal nature of resilience and its types related to education as competencies conducive to the effective functioning of students in a world of diversity, requiring continuous use of resilient resources. It can be argued that coping with anxiety as well as having resilience are key skills in the modern world and education, regardless of the education system. Therefore they seem to be universal for the well-being of every student.

The article will present math anxiety and math resilience as two relatively new research categories in contemporary educational studies. Then, arguments will be presented for their universality and the validity of their dissemination in modern education systems in a world of change and diversity.

Mathematics as an important domain in life, education and careers of young people has been liked by children at the stage of elementary education and it gives hope for the effective education of future mathematicians. Unfortunately, starting from the fourth grade of primary school, when mathematics becomes a separate teaching subject, a breakdown occurs and the first serious difficulties begin to appear (Ascraft, 2002; Dowker, Sarkar and Looi, 2016). In global research in recent decades, much attention has been paid to the emotions accompanying math education (Beilock and Willingham, 2014; Carey, Hill, Devine and Szucs, 2016; Caviola, Mammarella and Kovas, 2019). Math anxiety can be quite common emotion that appears in the fourth grade of primary school (Beilock, Gunderson, Ramirez and Levine, 2010).

There may be some explanations for lower achievements and the presence of math anxiety at such early stage of education (Cipora, 2015; Oszwa, 2020). Firstly, mathematics then becomes a separate teaching subject, isolated from the existing integrated education. Secondly, its structure becomes more complicated, with the introduction of symbols, formulas, patterns and laws. The way of teaching has been also changed, there has been less time for discovery and experimentation, and more energy has been spent on memorizing rules and practicing algorithms (Oszwa, 2020).

Mathematical achievements of students decrease with each subsequent year and this is not an isolated issue (Maloney et al, 2015). The situation has been reported similar in various teaching systems in Western culture. Additionally, the math education is complicated by the systemic differentiation of its teaching. In the countries with increasing cultural and didactic diversity, the issue of the emotional trend of math education can be useful in students' success and it can complement their cognitive competences and transferrable skills. It is worth making an effort and taking care of students' emotions related to math, because the negative experiences and unpleasant emotions related to learning it intensify with the age.

Much attention has been dedicated to research math anxiety in recent years (review: Oszwa, 2020). The results provide direction for educational activities. Awareness of the presence of this emotion, its early detection and measurement of its level can lead to effective intervention and prevention (Oszwa, 2005, 2017, 2020). Taking systemic actions aimed at supporting teachers in striving to develop students' emotional resilience from an early stage can be of great support. Particularly important in this context is an educationally useful form of resilience, understood as the ability not to give up despite difficulties and obstacles (Masten, 2001; Luthar, 2006).

Early prevention of math anxiety and the development of math resilience seem to be new challenges in elementary education, which constitutes the foundation of education at subsequent stages (Goodall and Johnston-Wilder, 2015; Pieronkiewicz and Szczygieł, 2019; Oszwa, 2023). This could be especially important in the contemporary world of great cultural and educational diversity, mass migrations of families with children and their need to adapt to new educational systems. Even though math could be the most international school subject compared to others, teachers nevertheless point out that there might be huge didactic differences in its systemic teaching. Providing students with emotional comfort and equipping them with resilience strategies could enable them to enjoy learning math in different environments in a relatively short time.

Math anxiety in contemporary research

The sources of math anxiety are primarily of social and external origin (Cipora, 2015; Oszwa, 2020). They are related to quite common educational stereotypes and negative attitudes towards math as a difficult field of knowledge, reserved only for particularly gifted people. A student's early personal negative and unpleasant experiences with math may further reinforce such attitudes. Another source of math anxiety could be educational stereotype

related to gender, especially the one according to which math is the male domain (Bedyńska and Rycielski, 2016; Turska and Oszwa, 2017, 2018). The education system - mainly behavioural, based on reinforcements and assessments - may also contribute to the development of math anxiety at an early stage of education (Klus-Stańska and Nowicka, 2005). Moreover, personality factors, such as trait anxiety, may concern some students who react with anxiety to all situations perceived as threatening, not only those related to math (Ramirez, Shaw & Maloney, 2018). They enlarge the group of students with isolated math anxiety.

Research on math anxiety allows for the identification of its several types, the level of which can be measured on scales with high psychometric parameters (Cipora, 2015). These include: learning math anxiety, testing math anxiety, fear of numbers, fear of math in everyday life, e.g. when estimating the amount to pay, calculating the amount of change when shopping, etc. (Oszwa, 2020).

Symptoms of math anxiety (Szczygieł and Cipora, 2016; Oszwa, 2020) have been analyzed in the research literature on different dimensions, which indicates the large scope of its impact (Ascraft, 2002). At the neuronal dimension, it has been observed increased activation of subcortical structures - the amygdala, hippocampus, intraparietal sulcus - responsible for the control of emotions and also for memory and calculations. In the physiological domain, the symptoms of math anxiety are typical for any other type of anxiety, such as: increased pulse, heart palpitations, sweating, stomach pain, diarrhoea, dry mouth, breathing problems, nausea, dizziness, tremors, etc (Oszwa, 2020). Most of them are not visible to the observer so a teacher may not be aware of them.

The symptoms of math anxiety could be also present at the cognitive domain (Ascraft and Faust, 1994). Math anxiety reduces capacity of working memory that is crucial in performing mental arithmetic operations (Ascraft, 2002). Part of it could be occupied by bothersome thoughts and worries (Oszwa, 2020). This emotion may be accompanied by a decrease in speech fluency and logical thinking, especially with additional social exposure, e.g. when solving a task at the board.

Math anxiety may have an indirect impact on the results of testing a student's cognitive development because the scales measuring intelligence include math tests. At the behavioural dimension math anxiety may manifest in avoiding mathematical tasks and tests, and reducing the effectiveness of solving them.

Long-term effects of math anxiety include avoiding life situations that require contact with math (Cipora, 2015; Oszwa, 2020), underestimating math value in everyday life, avoiding further education related to math, negative attitudes towards math and its teachers, feeling of lack of math competences throughout life.

The large number of studies have analysed math anxiety in connection with students' math achievements (review: Carey, Hill, Devine and Szucs, 2016). Based on the results, three explanations of this relationship have been established. According to the deficit hypothesis, low achievement in math causes math anxiety, and therefore learning math causes unpleasant emotions. According to the debilitating hypothesis, it is the math anxiety that causes low math achievement by occupying working memory. The most verified in practiced seems to be the reciprocity hypothesis, indicating a two-way influence of anxiety and achievement on each other (Oszwa, 2005, 2020).

Math anxiety has been also related to gender due to the results in studies involving women and men. It turns out that women score slightly higher on math anxiety scales (Bedyńska and Rycielski, 2016; Beilock et al, 2010). Three explanatory hypotheses have been indicated (Ashraft, 2000; 2019; Oszwa, 2020). Firstly, greater acceptance for open disclosure of anxiety in women means that they can write about it more boldly on measurement scales and admit to experiencing it. Secondly, the stereotyping of math education with the social perception of math as the domain of male may increase math anxiety in female. Moreover, research in recent years has drawn attention to the stereotype threat (Bedyńska and Rycielski, 2016). A higher level of anxiety was recorded in people who were subjected to the stereotype, even only indirectly, through comments, statements in their family and school experience. Thirdly, female greater self-awareness of experienced emotions may make it easier for them to connect life situations with statements on math anxiety scales, which has been reflected in their higher scores compared to male.

Math resilience in contemporary education

Resilience, mental toughness and flexibility have been differentiated in the research literature, but their common feature in educational practice is the processes and mechanisms that contribute to maintaining well-being despite obstacles, difficulties, and blockages (Masten, 2001; Luthar, 2006). In resilience understood as a process, three main sources of resources have been taken into account: 1) individual protective factors, 2) family protective factors, 3) environmental protective factors (Luthar, 2006). A few ranges of

resilience have been indicated: a) proper development despite difficulties, b) good psychosocial functioning despite adversities and c) return to mental stability after difficult experiences. These resilience forms have been analyzed in three resilience models: 1) compensatory, 2) protective and 3) developmental (Masten, 2001). Resilience mechanisms have been explained in the context of balancing adversities, reducing adversities, and gaining resistance to adversities (Oszwa, Domagała-Zyśk and Knopik, 2017).

Based on the general mental resilience framework, a specific model of resilience relating to math has been developed recently (Lee and Johnston-Wilder (2017) This model takes into account the ability to maintain positive emotions related to math despite the difficulties experienced by students when solving math problems in the process of learning (Johnston-Wilder, Lee, 2010). This model includes the theoretical background and dimensions of mathematical resilience. The theoretical background in this model of math resilience includes a compilation of four psychological and pedagogical concepts by authors well-known in education:

1. Carol Dweck (2017) – growth vs. fixed mindset: emphasizing the value of effort in the educational process, encouraging the student to make further attempts despite failure; effort and commitment - not abilities - are the driving force of success (Pieronkiewicz and Szczygieł, 2019; Yeager and Dweck, 2012);
2. Martin Seligman (1995) - pedagogical optimism: developing students' optimistic self-confidence in math; encouragement to persistent searching for solutions, approaching the problem from different perspectives; an optimistic child perceives failures as temporary, situation-related, and not as resulting from permanent character traits that cannot be changed (Lee and Johnston-Wilder, 2017);
3. Albert Bandura (2000; 2006) - self-efficacy, self-agency: belief in the possibility of achieving a goal and succeed; perseverance in pursuing the goal; not giving up despite difficulties; not breaking down under the pressure of adversity; internal locus of control (Oszwa, 2020);
4. Richard Ryan and Edward Deci (2020) - self-determination theory (SDT): teachers' satisfaction of students' universal psychological needs: a) autonomy, b) competence, c) relatedness; internal, self-determining motivation can be developed and maintained by meeting the listed needs of the student in the process of learning math (Ryan and Deci, 2000ab; 2020).

Sue Johnston-Wilder and Clare Lee (2010) have distinguished three dimensions of resilience related to math: 1) value - seeing and appreciating the usefulness of math in education and in life, 2) struggle - the belief that math requires difficulties and solving the problem does not come immediately even to mathematically talented people, so difficulty is its feature rather than exception. 3) growth - perception and awareness of opportunity for growth in math skills as a result of promoting a student's growth mindset instead fixed mindset (Dweck, 2017; Yeager and Dweck, 2012; Oszwa, 2020, 2023).

Shaping math resilience may be a challenge for education at its every stage (Lee, Johnston-Wilder, 2017). The behaviour of teachers could be a key factor in this process, first in elementary education and then in math lessons. To shape math resilience teachers are supposed to: present and prefer growth mindset rather than fixed mindset in teaching math; to appreciate the value and usefulness of math in education and life; to make students aware that math requires taking up challenges, and the solution usually does not come immediately; to support students in their difficulties. In the process of developing math resilience, it is worth assessing students' individual resilience resources, emotional support from parents, and supportive psychosocial environment. It is crucial to encourage students to math experimentation, develop their creative approach to math tasks, to promote team cooperation while improving problem-solving skills (Oszwa, 2023).

Math anxiety and math resilience as universal categories in research and education in a world of diversity

The review of research and analysis of their results provides the background to identify the following arguments in favor of the universality of math anxiety, independent of the education system. It might concern:

a) the very emotion of fear, which intensifies in societies in a world of change, uncertainty and the need to adapt. Adults' adherence to it leads to children also developing it through social learning (Bandura, 2000; 2006);

b) the specificity of mathematics as a school subject with particular complexity and spiral structure in subsequent stages of education (Ciesielski and Pogoda, 2005);

c) emphasizing the role of mathematics in times of intensive development of digital technologies and artificial intelligence, which leads to increased pressure from parents on their children's choice of educational fields related to mathematics and programming;

d) stereotypical understanding of mathematics as a male domain by many teachers (Turska and Oszwa, 2016; 2017), which may result in influencing female students with this way of thinking;
e) the presence of math anxiety among early education teachers who do not encourage their students to explore and experiment mathematically, but rather present this field as difficult to master.

Even though at the elementary education level mathematics is not taught in isolation, as a separate school subject, research results reveal fear of it already in this age group. The transmission of math anxiety from elementary teachers to female students has been proven by the results of research conducted in independent teams (Beilock et al, 2010). It is therefore worth taking actions to minimize unpleasant emotional experiences with math from an early stage. This may be a challenge for elementary female teachers, because many of them declare their aversion to math. They remember and report in the studies their own unpleasant emotions associated with math in the process of their own education, and feeling anxious about math in their current personal and professional lives (Baczko-Dombi, 2017). Therefore, systemic support in this area is needed in the form of continuous assistance from educational authorities and universities educating teachers (Beilock and Willingham, 2014; Oszwa, 2020, 2023).

As emerging challenges in early school education, math anxiety and math resilience represent two ends of one continuum. Prevention and reduction of math anxiety can be conducted by developing emotional resistance to problem situations, including mathematical problem solving (Knopik and Oszwa, 2019). Equipping students with transferable skills such as strategies for coping with difficulties and the psychological tools to help to return to well-being after experiencing adversity, may be important elements of contemporary multicultural education. In an era of widespread migration and mixing of educational systems, students are faced with constant adapting to new conditions. Resilience mechanisms, especially in math education, may prove to be their bridge towards achieving success despite difficulties.

Facing the diversity challenges could be an evidence of having resilient coping strategies. Awareness of their existence is an important factor both in learning, and teaching. With regard to math anxiety and math resilience, several areas of directions for taking them can be noticed from the stage of early school education.

Firstly, the current situation indicates that teachers of integrated education pay too little attention to the implementation of math goals included in the core curriculum. This leads to a reduction in opportunities for

students to construct math knowledge, as well as to gain positive experiences and emotions in the mathematization of life. The challenge for teachers is therefore to increase the frequency of creating situations conducive to the achievement of math goals included in the core curriculum from the first stage of education.

Second, a resilient teacher can teach their students resilient strategies. It is therefore crucial to equip teachers with knowledge about math resilience and math anxiety in the process of their university education. Since it has been relatively fresh knowledge, most of them may be unaware of its existence and mechanisms.

The third direction could be related to safe exposing students to more difficult math problem solving, so that they can experience opportunities to develop resilience with the adequate support when needed. An important factor could be the emphasis on the learning process (Dweck, 2017), and not only on its final result. This, in turn, brings up the topic of constructive perception of error and failure at the stage of early school education.

Math anxiety in early school education may particularly affect students whose teachers do not like math. They convey their negative attitudes to students by transmitting math anxiety (Szczygieł and Cipora, 2016; Oszwa, 2023). They teach as they were taught, not always effectively, often creating the presumption that math is a dangerous, uncreative school subject. Some teachers believe that failure to understand math is the result of a lack of effort and should be punished with a low grade.

An inspiring teacher, even at the stage of early school education, can be an effective remedy for math anxiety. The constructivist approach to math education has been based on promoting discovering of math principles by students, encouraging challenges in accordance with the belief that thinking occurs mainly while struggling with a problem (Dweck, 2017). Conversation and discussion in a group deepen curiosity and willingness to take risks in solving mathematical problems. Creating opportunities for math conversations and creative discoveries between students in teamwork has not been liked by teachers with math anxiety.

Interactive teaching through action, experimenting, discovering and exchanging ideas, creating opportunities to discover patterns, and not providing ready-made algorithms are strategies to counteract math anxiety. Presenting math as the opportunity to reason logically (Pieronkiewicz and Sczygieł, 2019), and not only the run to obtain the correct result when solving a task, could also be an antidote to the fear of math (Oszwa, 2023).

Similarly to math anxiety, math resilience can also be a universal research category, as indicated by the following arguments:

a) the need for resilience in everyday school life, which is full of difficulties, obstacles and new learning situations;

b) the need for special resilience in learning mathematics, which requires solving mathematical problems where difficulties are inherent elements of this process;

c) adaptation to new school situations, including the way mathematics is taught by students from other education systems, requires strong resilience, perseverance and the ability to face new obstacles;

d) including universal pedagogical approaches in resilience models, emphasizing skills such as growth mindset (Dweck, 2017), pedagogical optimism (Seligman, 1995), self-determination (Ryan and Deci, 2020) and self-efficacy (Bandura, 2006) helps to strengthen resilience and students' mental health not only in mathematics, but also in their general functioning at school and in everyday life situations.

A teacher who emphasizes the process of learning, solving problems, and appreciating the value of error can teach this. Effective communication techniques and a growth mindset instead of a fixed mindset are also crucial in teacher's approach (Dweck, 2017).

Alleviating math anxiety and developing math resilience are challenges of early school education for three social groups participating in this process: students, teachers and parents. Students can be helped by early identification of math anxiety and provided with techniques to deal with it, such as relaxation, mindfulness training, building self-confidence and responding constructively to negative feedback (Beilock and Willingham, 2014). Parents can contribute to alleviating their children's math anxiety through positive modelling, avoiding negative comments about math and communicating their own unpleasant experiences with it at school. Stimulating children to perform math analyzes in simple everyday situations might be a good strategy for creating math resilience and building positive associations with math (Ciesielski and Pogoda, 2005; Oszwa, 2020, 2023).

It is worth making efforts to ensure that math education based on the math resilience model promotes and supports a) positive attitude towards development, growth, effort, curiosity, b) the ability to overcome difficulties and treat them as challenges, c) optimism and sense of humour in difficulties,

d) self-efficacy (I can do it efficiently) and internal motivation with self-determination (Oszwa, 2023).

Conclusion

Prevention and alleviation of math anxiety in the digital world full of diversities and the development of resilient strategies for dealing with math are worth supporting in the triad of the teacher-student-parent relationship, regardless of the education system. At any stage of education, in addition to the cognitive component of teaching, it has been reccomended to focus on non-cognitive activities, such as:

1. minimizing the impact of risk factors for unpleasant emotions related to school,
2. breaking the chain of students' negative experiences with school,
3. strengthening the cycle of pleasant experiences and associates with school
4. creating conditions for developing openness to new experiences among students, openness
5. searching for experiences that neutralize and compensate for situations and risk factors of unpleasant emotions by building good teacher-student relationship),
6. changing the subjective assessment of situations by teaching students thepositive interpretation of their school experiences).

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