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Techniques for developing the emotional stability of high school students in the process of teaching mathematics: Ukrainian experience

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ABSTRACT

The purpose of the study is to find out the effective methods of the mathematics teacher's activity for the development of students' emotional stability in the process of solving stereometric problems. We simulated individual elements of the learning environment that can help students reduce anxiety and expand the potential for emotional resilience in math learning. Our experimental teacher tested special techniques to prevent or relieve anxiety when solving problems. It was important stimulate students' positive feelings, reduce the impact of negative emotions, and help increase students' endurance in a stressful exam situation. The main research tools are: observation of the emotional state of students in the process of solving problems; modeling of pedagogical situations in order to identify methods for the development of students' emotional stability; analysis, synthesis and systematization of observations of students' activities. When substantiating the effectiveness of techniques for developing students' emotional stability, the Delphi method was used. Stages of implementation: selection of experts; finding out 9 key factors, conducting interviews, analyzing and processing the results. The findings contribute to the expansion of knowledge about the conditions in which students' emotional resilience can develop. The techniques we offer can be built into most math lessons.

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1. INTRODUCTION

The problem of emotional stability of the individual has clearly exacerbated against the background of environmental, epidemic and military situations that seriously concern humanity today. Emotional stability can reduce the powerful impact of negative emotions, actualize the readiness to act rationally, and help increase the endurance of the individual in stressful situations. Emotional stability can be considered as one of the most important qualities of the personality, influencing the effectiveness of human activity in difficult unpredictable conditions [1]–[3].

Difficult unpredictable conditions of martial law have destroyed peaceful life in Ukraine. Armed aggression, constant air raids, power and communication interruptions have seriously affected educational processes, exacerbated the problems of quality education, and created new challenges. These problems have increased the need to study modern features and ways of forming the emotional stability of a Ukrainian schoolchild [4], [5]. Ukrainian researchers recognize the key role of teachers in the formation of students' emotional stability and the preparation of a mathematics teacher for such activities [6]–[8]. So, there were circumstances that the imposition of the martial law in Ukraine in February 2022 coincided with the implementation in the summer of 2022 of the plan of the Ministry of Education and Science of Ukraine on the mandatory passing of the external independent assessment (EIT) in mathematics by all the graduates of Ukrainian schools planning to study in higher education establishments. This fact actualizes the attention of researchers-teachers to the issues of mathematical anxiety in general, and mathematical anxiety of high school students in particular.

Research on the problems of mathematical anxiety in high school students is closely related to the problems of their emotional stability in learning [2], [9]. By the concept of "emotional stability" we mean complex integrative quality that provides the ability to withstand a state of uncertainty in emotionally tense conditions and carry out productive activities. The study of emotional stability and mathematical anxiety in teaching mathematics and the factors, determining them, as well as the ways and means of forming emotional stability, its support and preservation are now of particular relevance not only for the Ukrainian school. Xenofontos and Mouroutsou [2] note that over the past 11 years, almost 3 times as many papers have been published exploring the problems of mathematical stability than in the previous 39 years. This current observation conducted by the researchers Xenofontos and Mouroutsou [2] indicates an increase in international interest in the problems of mathematical anxiety and the problems of building emotional stability in mathematics education.

Historically, resilience entered the scientific discourse of human development in the 1970s as a result of research in psychology and psychiatry [2]. Scientists have subsequently concluded that resilience does not arise from special or exceptional qualities, "but from the everyday magic of ordinary, normative human resources in children's minds, brains, and bodies, in their families and relationships, and in their communities" [10]. Research, carried out by psychologists has shown that emotionally stable people are more likely to cope with difficulties by using active and relatable coping strategies rather than avoidance [11]. A number of studies on emotions suggest the possibility that for certain subjects there is an optimal level of anxiety above which, but also below which, performance decreases [12].

Emotional resilience research that has emerged in the field of psychology is obviously influencing the results of pedagogical research in the field of mathematics education. Teaching mathematics is an important area of pedagogical research for several reasons. First, it is important to explore students' emotions regarding mathematics because it is a core subject and is taught all over the world. Secondly, mathematics is a field that students usually attach to a fairly high level of perceived value, which sets the stage for experiencing high levels of both negative (e.g., anxiety before a difficult exam) and positive emotions (e.g., pride in a good grade) [13].

Learning math in school is often associated with negative attitudes and anxiety [9]. A significant link between math anxiety and math achievement can be argued [14]–[16]. Students who experience persistent anxiety in math learning tend to have lower math achievements [17]–[20]. Higher levels of math anxiety have also been associated with decreased attention in class [21]. Research also shows that low math ability is a prerequisite for math anxiety [22], [23]. Such students have a negative attitude towards mathematics. They experience serious difficulties solving math problems and even tend to avoid learning math [24], [25]. There is a point of view that mathematics requires special abilities and thinking skills, which are often considered to be inherited. Such beliefs, reflected in educational practice in many countries, can influence one's own expectations and those of others, influencing in turn the emotions of success or failure [26].

Stimulating students' positive beliefs and sense of competence in mathematics leads to better achievement in math learning [27]. Confidence in math knowledge can alleviate anxiety about learning [17], [28]. Such students demonstrate emotional resilience in their math learning, and are more assertive in their math learning even when faced with challenging life conditions [29]. However, in the field of mathematics, there is still a lack of tools to assess basic discrete emotions [13]. According to Bieleke *et al.* [13] the exception is the achievement emotion math questionnaire (AEQ-M). For example, researchers showed that AEQ-M scores for students on anxiety, anger, and shame were more strongly associated with academic achievement and parental expectations in China than in Germany, shedding light on important cultural differences. Separate studies indicate that students in Asian countries such as Korea and Japan exhibit comparatively low mathematical self-esteem, as well as high mathematical anxiety compared to students in less efficient countries [14]. On the other hand, some Western European countries, such as Finland, the Netherlands, Liechtenstein, and Switzerland, show "balanced" results with high mathematical performance and low levels of mathematical anxiety [30]. The assumption is that some cultural differences explain the differences in students' affect [14]. Interestingly, mathematical anxiety is rather loosely related to general intelligence [31]. More extensive research on anxiety and other emotions in math learning tends to focus on traits-like interpretations of it [26].

In summary, research on emotional resilience in mathematics teaching over the past decade has focused on the psychological components of mathematical resilience [2], [32], [33]; characteristics of mathematically stable individuals [34], [35]; the processes by which psychological and/or social factors promote or inhibit the development of mathematical resilience [36]; implementing pedagogical techniques to help students expand their potential for emotional resilience in math learning [26]. Recently, there has been a rapid increase in research on motivational interventions in educational psychology and didactics. Such interventions target specific psychological processes that are important sources of motivation and can have a surprisingly strong and lasting impact on students' motivation and learning performance [37], [38]. First of all, we are interested in the problem of emotional stability of high school students. Martino and Zan [12], investigated the relationship between the beliefs and emotions of high school students between the ages of 14 and 18. One of the conclusions is that high school students' attitudes are not seen as a personality trait useful for predicting behavior, but as an observer's construct capable of offering insight into an individual's intentional actions in a complex context, just like the study of mathematics: a multidimensional construct that incorporates beliefs and emotions and acts as a bridge between them [12]. Scientific approaches to the problem of emotional stability of high school students (students from 15 to 17 years old) are distinguished by a variety of views, lack of clarity and a low level of practical implementation. However, various researchers agree that it is important to prepare a learning environment that can help students reduce their anxiety about math [24], [39], [40]. The purpose of this study is to find out the effective methodical methods of the mathematics teacher's activity in the development of emotional stability of high school students in the process of solving stereometric problems.

2. RESEARCH METHOD

In our study, we modeled individual elements of a learning environment that can help students reduce anxiety in math learning. The main focus of the study is on the methodological techniques of a mathematics teacher who teaches high school students to solve stereometric problems. To help students expand their potential for emotional resilience in math learning, our experimental teacher creates special situations to prevent and remove negative emotions (anxiety and helplessness) when solving problems that are typical for Ukrainian texts of EIT in mathematics. The students are clearly informed that the proposed problems are taken from the collections of texts of the EIT in mathematics. The main goal of the teacher is to organize the process of solving problems in such a way as to reduce the impact of negative emotions, actualize the readiness to act rationally, and help increase the endurance of students in a stressful exam situation. It is important for us to stimulate students' positive beliefs and sense of competence in mathematics.

The main tools of the study were: observation of the emotional state of students in the process of solving stereometric problems; modeling of pedagogical situations in order to identify effective techniques for the development of students' emotional stability; analysis, synthesis, systematization and generalization of observations of students' activities in the process of solving problems. In this article, we consider the methods of methodological activity of a mathematics teacher in the process of solving the following 3 problems that are important from the point of view of developing students' emotional stability:

- Task 1. Given a triangle ABC, the vertices of which have coordinates A (-2; 6; 3), B (-2; -2; 3), and C (4; -2; 3). Find the length of the median BM.
- Task 2. The lateral edges of a triangular pyramid are perpendicular in pairs and are equal to a, b, and c. Find the volume of the pyramid.
- Task 3. In a regular pyramid, the area of the base is one-third of the total surface area. Find in degrees the dihedral angle at the base of the pyramid.

To identify effective techniques for developing emotional resilience, the expert evaluation method (Delphi method) was used. The main stages of implementing this expert evaluation method in our study are: selecting experts, identifying various factors, conducting interviews, analyzing interview results, and processing the results. The experts included mathematics teachers and lecturers from the pedagogical university, who train mathematics teachers, and 12 individuals were involved in the study.

The survey form listed 9 factors important for the formation and development of students' emotional resilience in the process of solving problems: i) the ability of the mathematics teacher to provide a high level of emotional support to students; ii) the ability of the mathematics teacher to teach students to find different ways to overcome difficulties; iii) the skill of the mathematics teacher to offer students an unexpected approach in the process of solving a stereometric problem, which immediately transforms the problem from complex to simple; iv) the skill of the mathematics teacher to consider how to motivate students when developing teaching materials; v) the ability of the mathematics teacher to stimulate positive beliefs in students and a sense of their own competence in mathematics; vi) the skill of the mathematics teacher to draw students' attention to the possibility of different ways of reasoning in the process of solving stereometric problems; vii) the ability of the mathematics teacher to relate the content of learning to students' personal goals; viii) the ability of the mathematics teacher to reduce students' anxiety during problem-solving and increase the confidence of anxious students in learning; and ix) the talent of the mathematics teacher to express positive emotions in the process of solving stereometric problems. The methods of mathematical statistics used in the study are based on ranking. In this case, each expert assigns a rank from 9 to 1 to each factor (in descending order to determine their relative significance).

A necessary condition for the reliability of the collective assessment is sufficient coordination of the opinions of the surveyed experts. To determine the agreement of group assessments, the researchers used the coefficient of concordance - a composite rank correlation coefficient for the group of experts. The processing of the results of the expert survey was carried out, as shown in Table 1. For each factor, we found the total rank, the average rank, based on which we determined the rank of the factor, as in Table 2 and Figure 1.

Table 1. Factor evaluation ranks

Number of the factor	1	2	3	4	5	6	7	8	9
Expert 1	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}
Expert 2	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}
…….	…	….	…	…	…	…	…	…	…
Expert 12	X_{121}	X_{122}	X_{123}	X_{124}	X_{125}	X_{126}	X_{127}	X_{128}	X_{129}

Table 2. Factor ranks

Factors	1	2	3	4	5	6	7	8	9
Average rank	2.83	7.5	6.25	5.58	7.5	6.33	2.5	3.42	3.17
Sum of ranks	34	90	75	67	90	76	30	41	38
Rank of the factor	6	1	4	3	2	5	9	7	8

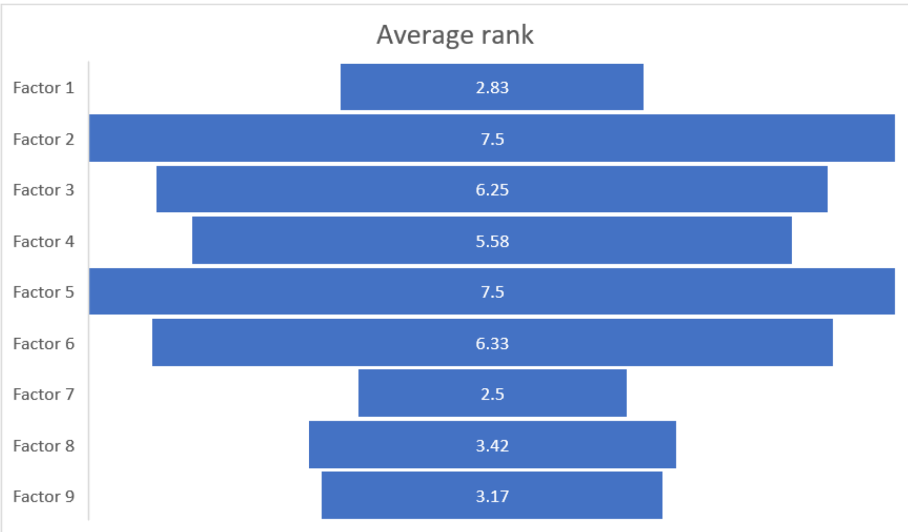

Figure 1. Rank of the factor

Thus, the most significant were:
- The ability of the mathematics teacher to teach students to find different ways to overcome difficulties;
- The ability of the mathematics teacher to stimulate positive beliefs in students and a sense of their own competence in mathematics; and
- The skill of the mathematics teacher to draw students' attention to the possibility of different ways of reasoning in the process of solving stereometric problems;

The skill of the mathematics teacher to offer students an unexpected approach in the process of solving a stereometric problem, which immediately transforms the problem from complex to simple. The assessment of the consistency of experts' opinions was carried out using the coefficient of concordance, calculated according to (1):

$$W = \frac{12}{m^2(n^3-n)} \sum_{j=1}^{n} \left[\sum_{i=1}^{m} x_y - \frac{m(n+1)}{2} \right]^2 \quad (1)$$

In this case, m=12 and n=9. The obtained value W=0.7027, which on the rank correlation coefficient scale lies within the interval (0.6; 0.8), indicates good consistency of the experts' conclusions. To verify the coefficient of concordance, we will find the critical value at the significance level α=0.05 and determine the degrees of freedom q=9−1=8. Using Pearson's table, we will find the value χ^2_{cr} (8;0.05)=15.5. The actual value will be calculated using (2):

$$\chi_f^2 = m(n-1)W \quad (2)$$

since $\chi_f^2 > \chi_{cr}^2$ then the conclusion can be made regarding the significance of the concordance coefficient that proves the validity of the obtained conclusions.

The key factors identified by our experts for the formation and development of students' emotional resilience during problem-solving align with the findings of other studies. In particular, research highlights the important role of teachers in engaging students through various pedagogical methods that promote cognitive and behavioral activity. These studies show that teachers can foster a positive learning environment, where students have a higher likelihood of mastering the material as they are given more opportunities to actively participate in the learning process [27], [41]. The results suggest that math exercises enhance math competence and simultaneously strengthen learner's confidence and math self-efficacy, which consequently leads to a decrease in negative emotions [37], [42].

3. RESULTS AND DISCUSSION

Despite the brevity (3 specific situations), the current relevance of the intervention program has shown a positive effect on alleviating the anxiety of high school students regarding the solution of stereometric problems during the EIT in mathematics, increasing their readiness to carry out productive activities in emotionally stressful conditions.

3.1. Situation 1

The mathematics teacher draws the students' attention to the possibility of different ways of reasoning in the process of solving problems of the EIT in mathematics. For example: a triangle ABC is given, the vertices of which have coordinates A (-2; 6; 3), B (-2; -2; 3), and C (4; -2; 3). Find the length of the median BM.
Method 1, Figure 2.

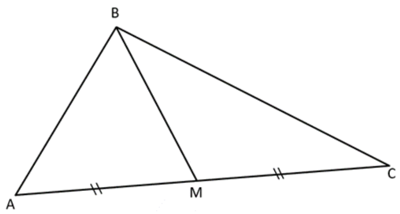

Figure 2. Figure for task 1

M is the middle of the segment AC: M (x; y; z), where $x = \frac{-2+4}{2} = \frac{2}{2} = 1, y = \frac{6+(-2)}{2} = \frac{4}{2} = 2, z = \frac{3+3}{2} = \frac{6}{2} = 3$.
Therefore, M (1; 2; 3).
Let us apply the formula for the distance between points;

$$BM: d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2}$$
$$d = \sqrt{(1+2)^2 + (2+2)^2 + (3-3)^2} = \sqrt{9+16+0} = \sqrt{25} = 5.$$

Therefore, BM=5.
Method 2, Figure 3.

It can be seen that the third coordinates of the specified points are equal, so all points are located in a plane that is parallel to the xOy plane. Consider points A_1 (- 2; 6), B_1 (-2; -2), and C_1 (4; -2) in the xOy plane. Let us build them.

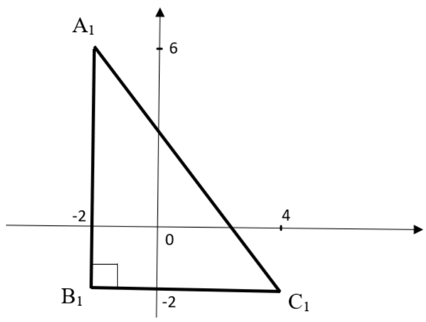

Figure 3. Figure for task 1 (method 2)

$\Delta A_1B_1C_1$ is rectangular, $\angle B_1$=90°, A_1C_1 is the hypotenuse. That is, you need to find the length of the median drawn to the hypotenuse. As it is known $m_c = \frac{c}{2}$. It is clear that A_1B_1=8, B_1C_1=6, therefore A_1C_1=10 (properties of a triangle similar to the Egyptian one). So, $m_c = \frac{10}{2} = 5$.
Method 3, Figure 4.

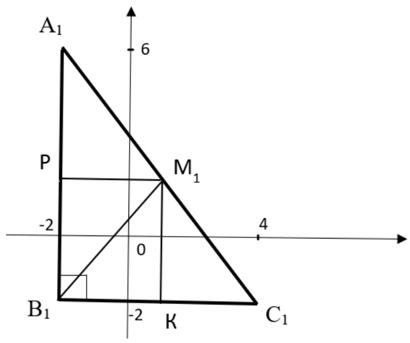

Figure 4. Figure for task 1 (method 3)

Analogous to method 2 of point A_1 (- 2; 6), B_1 (-2; -2), and C_1 (4; -2). Since B_1M_1 is the median by condition, then $A_1M_1=M_1C_1$. Let us lower the perpendiculars from M_1 to A_1B_1 and B_1C_1. $A_1B_1 \parallel M_1K$, $B_1C_1 \parallel M_1P$. According to Thales' theorem: $A_1P=PB_1$, $B_1K=KC_1$. Since B_1C_1=6, then B_1K=3. Since A_1B_1=8, then PB_1=4. B_1M_1 is found with ΔB_1M_1K ($\angle K$=90°) by the Pythagorean theorem:

$$B_1M_1{}^2 = 3^2 + 4^2$$
$$B_1M_1{}^2 = 9 + 16$$
$$B_1M_1{}^2 = 25$$
$$B_1M_1 = 5.$$

The results of our observations: the students were pleasantly surprised by the variety of possible reasoning about how to find the median, specified in the problem. They were reassured by the fact that even forgetting the formulas for finding the middle of the segment and the length of the segment is not an obstacle to finding the correct answer in this problem. In fact, the experiment discussed many more possible ways to find the length of the desired median. We have listed here those which were perceived by the majority of students with pronounced positive emotions.

3.2. Situation 2

A math teacher offers students an unexpected approach to solving a stereometric problem that suddenly turns the problem from difficult to easy. For instance: the lateral edges of a triangular pyramid are perpendicular in pairs and are equal to a, b, and c. Find the volume of the pyramid. The solution: the students' standard reasoning begins with the execution of a drawing according to the condition of the problem, as in Figure 5.

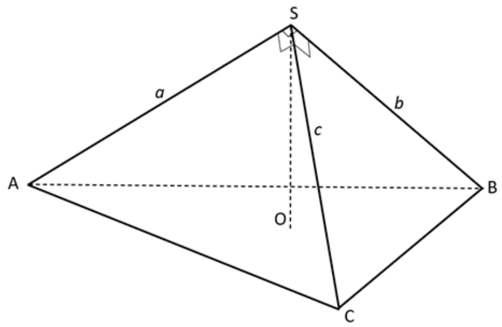

Figure 5. Figure for task 2 (method 1)

$V = \frac{1}{3} S_{\text{base}} \cdot H = \frac{1}{3} S_{\Delta ABC} \cdot SO$. To find the area of the triangle ABC, the students suggest using Heron's formula, having previously found the lengths of the sides of the triangle: $AC = \sqrt{a^2 + c^2}$, $AB = \sqrt{a^2 + b^2}$, $BC = \sqrt{c^2 + b^2}$.

However, already at the stage of finding the semi-perimeter of the ABC triangle, it becomes obvious that the expression transformations are too cumbersome. In addition to the above -mentioned, the uncertainty of the position of the base of the height of the depicted pyramid is frightening in this problem. Students have a feeling of helplessness in the face of such difficult situations that can happen during the EIT in mathematics. The teacher should calm the students down and demonstrate an impressive technique for turning a complex situation into a simple one. It is important that the teacher emotionally beautifully presents the technique of simple turning of a given pyramid into a more convenient position for calculating the volume, as in Figure 6.

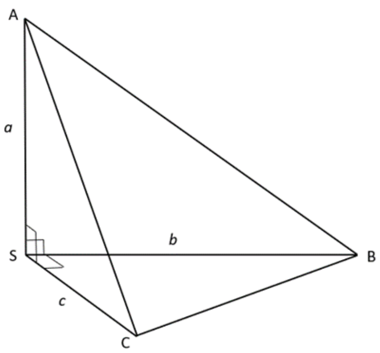

Figure 6. Figure for task 2 (method 2)

Obviously, the volume of the pyramid did not change when it was turned over. However, now V=1/3 S_base·H=1/3 S_ΔSBC·AS=1/3·1/2·b·c·a=1/6 abc. Problem is solved!!!

The results of our observations: The students were impressed by the simplicity and originality of transforming a complex situation into a fairly simple case. Such an experience turned out to be extremely important for students, because it formed an idea of the possibility of a different approach to the representation of the problem data, if the method of solving the problem leads to excessive transformations and significant time costs.

3.3. Discussion

Help students link learning content to their personal objectives and thus bind internal and external reasons for completing a task is a promising approach to motivational interventions in the classroom [43]. Lack of interest in mathematics can arise from the failure to master certain topics and further increase anxiety about mathematics, as well as reduce confidence [44]. Teachers should carefully provide the learning environment with motivational incentives [18]. Problem-solving is central among mathematical activities. When compiling a selection of problems for a math lesson, teachers should take care to reduce students' anxiety when solving problems and increase their confidence in learning anxious students [45]. When developing teaching materials, consideration should be given to how to motivate students [46], [47].

In teaching math, it is important to teach students to look for different ways to overcome difficulties. Thanks to this, in emotionally stressed situations, students will know how to act and will be able to control their emotions. Emotional stability, especially in conditions of uncertainty, the ability to find a way out after failures or difficult life situations, to be ready to start over is a vital quality for modern students. It can and should be shaped. Appropriate techniques can be perfectly integrated into most lessons of mathematics in high school.

Positive emotions of the teacher are important for the formation and development of students' emotional stability in the process of solving problems. The ability of mathematics teachers to provide high level of emotional support in teaching mathematics depends on their methodological competence. Bandura [48] social-cognitive theory states that teachers with higher self-efficacy put more effort into motivating students and improving their skills and are more persistent in their efforts [49]. Emotional support for teachers refers to teachers' ability to create a warm and respectful classroom climate by fostering positive teacher-student and student-student interactions, noticing students' difficulties, acknowledging students' emotions and thoughts, and supporting students' emotional moods. The emotional support provided by the teacher is of great importance for students' interest [50].

We agree with Martino and Zan [12], that tracing the "history" of the attitude construct and discussing the results obtained is a very important step in the development of research in the field of mathematics education. Intrinsic value is defined as the pleasure a person derives from performing a task and associates with his personal interests. Interventions that promote the development of students' value beliefs are very important for practice, since the values of persuasion influence students' academic development in terms of effort and perseverance in different school subjects [38]. Brief motivational interventions, such as interventions focused on students' perceptions of the relevance of the learning material, can have a long-term impact on student motivation and performance [38]. Researchers identify various components that positively influence students' subjective evaluation of a particular task, including its intrinsic value (satisfaction with completing a task), achievement value (personal importance of completing a task), and utility value (the usefulness of a task to achieve one's own goals), [26]. Personalization of context and special choice of tasks attract the attention of students with low personal interest in mathematics and help them become more engaged in learning activities [51].

The question of how reliably emotions can be deduced from observations, especially complex, subtle, or partially repressed emotions, remains open [26]. It can be assumed that the strategy of influencing students' control and value assessments can be an effective measure to promote positive emotions while reducing negative ones [52]. General anxiety disrupts current working memory processes, as anxious people pay attention to their obsessive thoughts and worries rather than to the task at hand [31].

In order to link learning avoidance to achievement, it is important to understand whether students are applying the right strategies in learning and practice, seeking help when needed, and using their study time effectively [11]. Results of research by Jenifer *et al*. [21] demonstrate the important role that students' exam preparation behavior plays in their math performance, and suggest that emotional resilience in relation to mathematics can be a critical factor in this regard.

This study has certain limitations. It does not claim to be representative, as it was conducted only among specific groups of students formed for preparation for the external independent testing in mathematics. The total number of 11th-grade students (high school graduates) involved in the study is 27. We plan to continue the research in the future to collect a more extensive dataset. Future research should also consider different contexts, as the current study was conducted solely in Ukraine, which is in a state of war. Conducting similar studies in peaceful countries would allow for comparisons and could highlight some key individual and contextual factors that contribute to high effectiveness.

4. CONCLUSION

The main characteristics of the emotional stability of the individual, in our opinion, are the ability to preserve the essential positive qualities in difficult life circumstances. Since emotional stability is one of the most important qualities of a person, it needs to be formed and developed in the process of schooling. That is, the process of forming emotional stability in students of different age categories should be one of the objects of attention of teachers of various subjects, including math teachers.

This study sheds light on some techniques for developing the emotional resilience of high school students in the process of preparing them for final tests. In particular, the most problematic educational material for students was chosen-solving stereometric problems. Our study has 2 main findings. Firstly, it is both necessary and possible to develop the emotional stability of high school students in the process of teaching mathematics. Secondly, it is important to link the content of the learning to the students' personal goals and thus link the internal and external reasons for completing the tasks. For the formation and development of students' emotional stability in the process of solving problems, the ability of the mathematics teacher to provide a high level of emotional support to students is important. Thus, our findings contribute to the expansion of knowledge about the conditions in which students' emotional resilience in learning can develop, as well as how such conditions can be implemented in the practice of teaching mathematics in high school. In future studies, it will be necessary to continue the study of techniques for developing the emotional resilience of high school students in teaching mathematics, considering a variety of contexts and using adequate research projects to be able to verify the reliability and generalizability of these findings.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

ETHICAL APPROVAL

The research related to human use has been complied with all the relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration and has been approved by the authors' institutional review board or equivalent committee.

DATA AVAILABILITY

Derived data supporting the findings of this study are available from the corresponding author, [LM], on request.

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