

Interdisciplinary connections of Mathematics and Literature in the preparation for External Independent Assessment of Humanities students

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Abstract. This article examines the issue of finding new methodological approaches to the development of problems that can contribute to the preparation of 'Humanities' students to pass the state final certification in the format of External independent assessment (EIA). The study analyzes the existing development of methods of qualitative mathematical training of students of humanities classes who study Mathematics according to the basic level program. In particular, the authors of the article were interested in the use of interdisciplinary connections between Mathematics and humanitarian disciplines. The authors of the article identified cross-curricular problems as a means of forming students' motivation to study Mathematics, as well as a toolkit for measuring their level of readiness to solve typical problems of EIA. The researchers set a goal to develop cross-curricular problems following the EIA program based on the plot of Bulgakov's novel 'The Master and Margarita'. An experiment was conducted to confirm the effectiveness of the use of the system of interdisciplinary problems in the preparation for the EIA of humanitarian students. The obtained results confirmed that the implementation of problems in which the intersubject connections of Mathematics and Literature are realized has a more significant effect on both increasing the motivation of students to study Mathematics and their mathematical preparation.

1. Introduction

Since 2021, passing the final state certification in the format of EIA has become mandatory in Ukraine for all graduates of secondary education institutions. The statistics of the results of the 2021 EIA show that more than 32% of high school students did not pass the EIA in Mathematics, which is almost twice the number of students who did not pass the EIA in other academic subjects. Such results are explained by the low level of motivation of students studying in humanities classes to learn mathematical disciplines. Therefore, to increase the interest of these high school students, and to help them prepare for the EIA in Mathematics, the authors of the article come up with a proposal to develop interdisciplinary Mathematics problems for students of humanities classes, which are based on the content of specialized disciplines.



The purpose of the article is to develop and implement cross-curricular problems per the extracurricular program based on the plot of Bulgakov's novel 'The Master and Margarita' [1] to prepare students of humanities classes for the state final certification in Mathematics in the format of EIA.

2. Related works

Investigating the problem of the relationship between Mathematics and Art, Damrau et al. [2] devoted their work to the following areas: mathematical learning based on artistic procedures, artistic objects as a source of inspiration for studying Mathematics, Image Statistics, Symmetry and Geometry. Analyzing the conclusions of scientists, the authors of this article chose mathematical learning based on works of art as their direction.

Searching for research in this area helped the authors of this paper get acquainted with the work of Fujiwara [3], who believes that although Literature and Mathematics are related to creativity and appreciate beauty and harmony, their methodologies differ. Mathematics is based on universal logic pursued by a mathematical sense and an aesthetic sensibility, while Literature requires originality and sensitivity to words. We accepted this challenge and decided to combine the aesthetic sensibility of Mathematics with the literary sensibility of words. It was also decided to show that it is possible to connect Literature and Mathematics for Humanities students to increase their interest in studying Mathematics and increase their basic knowledge. This opinion is consistent with the conclusions of researchers Johansen et al. [4], who see that the involvement of creativity (the nature of problems and the way they are presented) in Mathematics classes contributes to increasing the interest of students in studying and researching mathematical problems, improves their basic knowledge of the subject. We agree that mathematical problems related to literary works will help students in the Humanities to become interested in Mathematics and prepare for EIA.

Tisngati and Genarsih [5] assign a significant role in the study of Mathematics to mathematical problems. In their opinion, there is a clear connection between solving mathematical problems and students' mathematical and reflective thinking. That is why we have created a system of mathematical problems for the preparation of high school students who study in humanities classes and classes with a creative inclination for the EIA in Mathematics.

Weinstein [6] believes that children's literature is an alternative method of learning Mathematics for elementary school students. She sees the advantages of using children's literature in the fact that, thanks to the books, students can understand where exactly the knowledge of Mathematics is used in everyday life and how it is related to other educational subjects. Based on this idea, the scientist wrote a book that helps students learn to add and subtract fractions using different calculation methods.

Ochkov and Andreas [7] give examples of the integration of Classical Literature in Mathematics classes. They analyzed such works of art as Chekhov's 'The Tutor', Dostoevsky's 'The Gambler', Verne's 'Twenty Thousand Leagues Under the Sea', Molière's 'Le Bourgeois Gentilhomme', Rachinskij's '1001 Tasks for Mental Calculation' [8] and demonstrated what mathematical problems can be developed on their basis. We studied the researchers' approach and decided to demonstrate the connection of Bulgakov's novel 'The Master and Margarita' [1] with Mathematics by the method of composing a system of mathematical problems.

3. Methods

The system of problems was compiled following the six content lines (sections) of Mathematics (Numbers and Expressions; Equations, Inequalities and their Systems; Functions; Combinatorics, Probability Theory, Statistics; Planimetry; Stereometry) and types of problems that are found in EIA. When compiling the problems, it was taken into account that all problems will be open-ended with a short answer. We also used the following methods:

- primary research and information gathering: analysis of external independent assessment tests in Mathematics of previous years from the main, additional and trial sessions [9];
- systematization and structural analysis: selection of the main content lines and their sections, which are found in EIA;
- data processing: the creation of a system of problems with an open, short answer for preparation for the EIA in Mathematics based on the plot of Bulgakov's novel 'The Master and Margarita'.

Based on such research methods, a system of problems was compiled for the preparation for the EIA in Mathematics of high school students who study in 'Humanities' and classes with a creative inclination. It is given examples of problems of the developed system (table 1).

Table 1: A system of problems in Mathematics for preparation for EIA, based on Bulgakov's novel 'The Master and Margarita'.

Academic discipline	Section	Topic	Problem
Algebra and Analysis	Numbers and Expressions	Real numbers	Two friends read the novel 'The Master and Margarita'. One of them took the book from the library, which had 382 pages, and the second read the book online, which had 124 pages. It is known that the second friend read 105 pages. Determine how much does this compare with the pages of a book on paper?
		Relationships and proportions Percentages. Text problems	In Mikhail Bulgakov's novel 'The Master and Margarita', the story about Pontius Pilate occupies three chapters in a ratio of 19:108. Find the number of pages of this story, if it is known that the rest of the novel is 324 pages. Calculate the percentage ratio of this story in the novel, and round the result to the nearest hundredth.
		Exponential, logarithmic, trigonometric expressions and their transformations	Calculate $\log_{a+b} c$, where a is the floor of Lesha Lykhodeev's apartment, b is the entrance number of the house where Lesha Lykhodeev lived, and c is the number of Margaritas found by Woland's entourage in Moscow.
		Rational, irrational, power expressions and their transformations	Calculate $\frac{(a+7)^{24b}}{c^2}$, where a is the room number of the master in the Stravinsky clinic, b is the number of chapters in the novel 'The Master and Margarita', c is the amount of money that the police confiscated from Nikanor Ivanovich.
		Linear, quadratic, rational equations and systems of equations	x_1 and x_2 are the roots of the equation $x^2 - \frac{a}{2}x - b = 0$, where a is the entrance number of the house where Lesha Lykhodeev lived, b is the floor of Lesha Lykhodeev's apartment. Calculate $x_1^2 + x_2^2$ without solving the equation.

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Academic discipline	Section	Topic	Problem
Functions		Irrational, trigonometric equations and systems of equations	Solve the equation $8\sqrt{x-a} = b$, where a is Lesha Lykhodeev's apartment number, and b is the number of chapters in the novel 'The Master and Margarita'.
		Exponential, logarithmic equations and systems of equations	Solve the equation $2^{x-a} = \frac{1}{b}$, where a is the entrance number of the house where Lesha Lykhodeev lived, and b is the number of chapters in the novel 'The Master and Margarita'.
		Inequalities and systems of inequalities	Solve the inequality $(x - \sqrt{a})^2 < b$, where a is the number of Margaritas found by Woland's entourage in Moscow, and b is the amount of money that the police seized from Nikanor Ivanovich. Write down the largest integer in the answer.
		Solving problems using equations and systems of equations	As you know, Lesha Likhodeev lived on Sadova Street in house number 302-bis, apartment 50. Find out at which entrance and on which floor this apartment is located, if it is a five-story building and if there are no apartments in the first five entrances on the first floors. Keep in mind that there are two apartments on the other floors.
	Number sequences		As you know, there was a deposit of 10,000 in the Master's savings account. What amount of the deposit would be in the master's savings account in three years, if the annual interest rate was 15%?
		Functional dependence	Find the domain of the function $y = \sqrt[n]{a-3x}$, where a is Lesha Lykhodeev's apartment number, and n is the floor on which Lesha Lykhodeev's apartment is located. In the answer write down the largest two-digit number that belongs to the domain of the function.
		Linear and quadratic functions	Find the maximum value of the function $y = c - bx - x^2$, where b is the entrance number of Lesha Lykhodeev's house, and c is the denomination of banknotes that fell into the hall during Woland's performance in Variety.
		Power, exponential, logarithmic and trigonometric functions	Specify the smallest value of the function $y = \operatorname{acos}(2xb) + a$, where a is the denomination of banknotes that fell into the hall during Woland's performance in Variety, b is the amount of money that the police confiscated from Nikanor Ivanovich.
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Academic discipline	Section	Topic	Problem	
Geometry		The derivative of a function	Find the value of the derivative function $f(x) = \sqrt{a - \frac{b}{2}x}$ at the point $x_0 = -\frac{b}{3}$, where a is the denomination of banknotes that fell into the hall during Woland's performance in Variety, b is the entrance number of Lesha Lykhodeev's house.	
		Anti-derivative and definite integral	Calculate the area of the shape bounded by the lines $y = x^{a/2}$, $y = \frac{b}{c}$, $x = 0$, where a is the entrance number of the house where Lesha Likhodeev lived, b is the amount of money that the police seized from Nikanor Ivanovich, c is the apartment number of Lesha Lykhodeev.	
		Combinatorial analysis	As Koroviev said, the hostess of the ball must certainly have the name of Margarita. In Moscow, they found 121 Margaritas. In how many ways can you choose the 2 Margaritas you need?	
	Combinatorics	The probability of a random event	As we know, Margarita marked with her fingernail one of the points on the seven of the spades map to check the accuracy of Azazello's shooting. What is the probability that she hit the top right corner point?	
		Planimetry	Elementary geometric shapes on the plane	The segment, the length of which is equal to $(a + 10)$ cm, where a is the number of the entrance of Lesha Likhodeev's house, is divided by points into four equal segments. Determine the distance between the midpoints of the obtained extreme segments.
			Triangles	In the MNKP rectangle: $MN = a$ cm, $NK = a + 2$ cm, A and B are the midpoints of the sides NK and KP, respectively. Find the area of the triangle MAB (in cm^2), if a is the number of the entrance of Lesha Likhodeev's house.
Right triangles	The hypotenuse AC of an isosceles right triangle ABC is $(a - 1.4)$ dm. The square MNKP is inscribed in this triangle, two of whose vertices are on the hypotenuse, and the other two are on the legs, where a is the number of the entrance of Lesha Likhodeev's house. 1. Determine the area of triangle ABC (in dm^2). 2. Calculate the area of the square MNKP (in dm^2).			
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Academic discipline	Section	Topic	Problem
		Parallelogram, rhombus, trapeze, Polygons	In a rectangular trapezoid MNKP ($MP \parallel NK$), the diagonal MK is perpendicular to the lateral side of KP. Find the length of this diagonal (in cm), if $MP = 3a$ cm, $NK = c - 2$ cm, where a is the number of the entrance of Lesha Likhodeev's house, c is the denomination of the banknotes that fell into the hall during Woland's performance in Variety.
		Rectangle Square	The bisector of angle A of rectangle ABCD intersects its long side BC at point K. Determine the radius of the circle (in cm) circumscribing the rectangle if $BC = 4c$ cm, $AK = 2a\sqrt{2}$ cm, where a is the floor of Lesha Likhodeev's apartment, c is the number of Lesha Likhodeev's entrance.
		Circle. Polygons	During the execution of Yeshua, at the foot of Bald Mountain, the ala cordoned off the hill. Calculate the length of the radius of the base of the hill, if it is known that the hill was cordoned off by 50 soldiers, each of which occupied 1 meter, and the free rise from the Jaffa Road was 4 meters.
		Coordinates and vectors on the plane. Geometric displacements	In the Cartesian coordinate system, a circle is described near the triangle ABC, given by the equations $x^2 + y^2(2ac) = 10a + 3c$. Determine the length of the side BC if $\angle A = 9a^\circ$, where a is the floor of Lesha Likhodeev's apartment, and c is the number of the entrance of Lesha Likhodeev's house.
Stereometry		Coordinates and vectors on the plane. Geometric displacements of lines and planes in space	The base of a straight prism $ABCD A_1 B_1 C_1 D_1$ is an isosceles trapezoid ABCD. The base AD of the trapezoid is equal to its height and c times greater than the base BC. A plane is drawn through the side edge CC_1 of the prism parallel to the edge AB. Find the area of the resulting section (in cm^2), if the volume of the prism is $112c \text{ cm}^3$ and its height is $(c + 2)$ cm, where c is the number of the entrance to Lesha Likhodeev's house.
		Prism	The 'Drumlit House', where the critic Latunsky lived, has 8 floors, each 3 meters high, the base of the house is a square with a side of 7 meters. Calculate the volume of this building.

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Academic discipline	Section	Topic	Problem
		Pyramid	In a regular quadrangular pyramid, the side edge is $3a$ cm, and the side of the base is $(2a1)\sqrt{2}$ cm. Determine the volume of this pyramid (in cm^3), if a is the floor of Lesha Likhodeev's apartment.
		Bodies of rotation	The volume of a body created by the rotation of an isosceles triangle about a height drawn to its base, equal to $0,5a$ cm, is $10a\pi$ cm^3 . Calculate the length of the generatrix of the body of revolution (in cm), if a is the number of chapters in the novel 'The Master and Margarita'.
		Coordinates and vectors in space	In the Cartesian coordinate system, the points $A(c; 4; b)$ and $B(2a; b; 7)$, are given in space, where a is the number of the floor on which the apartment of Lesha Likhodeev was located, b is the denomination of the banknotes that fell into the hall during the time of Woland's performance in the Variety with c – the number of chapters in the novel 'The Master and Margarita'. Point C is the midpoint of segment AB. 1. Find the abscissa of point C. 2. Calculate the vector length \overline{AC} .

4. Results

We conducted the experiment to determine the effectiveness of the preparation of humanities students for the EIA in Mathematics. The basis of the research was secondary education institutions in which masters of the speciality 014 Secondary Education (Mathematics) completed a pedagogical internship in the 11th grade, who study Mathematics at the standard level: Kryvyi Rih educational complex No. 81, Kostyantynivskyi institution of general secondary education I-III degrees No. 1, Kostyantyniv educational complex 'General education school of I-III degrees', Kramatorsk educational complex 'General education school of I-III degrees No. 6', Kryvyi Rih general education schools No. 75 and No. 122. Masters who were involved in the experiment attended training to get acquainted with its purpose and tasks and took part in the development of methods for conducting classes using a complex system of problems. The teachers were warned about conducting the experiment and helped the students in conducting it.

The main tasks of the experiment were:

- analysis of test tasks of external independent assessment in Mathematics;
- a study of the process of preparing high school students for EIA in Mathematics in secondary education institutions, for Humanities students;
- development and introduction into the educational process of a system of problems for preparation for the EIA in Mathematics based on Bulgakov's novel 'The Master and Margarita';

- analysis of the results of the experiment.

Control (CG) and experimental groups (EG) were formed in a non-random manner. To ensure equal conditions for conducting the experiment, the formed groups were examined for statistical equivalence by analyzing the level of knowledge and skills shown by students during the monitoring trial testing of the EIA in Mathematics at the beginning of the experiment.

The experiment was conducted for six weeks, and 145 students took part in it: 70 in CG and 75 in EG:

- the control group (CG) included students from the following schools: Kryvyi Rih educational complex No. 81, Kostyantynivskyi institution of general secondary education of I-III degrees No. 1, Kryvyi Rih general education school No. 75. Preparation for the EIA in Mathematics in these classes was carried out according to traditional methods. Students were offered mathematical problems for repetition on various topics of the school Mathematics course, which are presented at the external examination;
- to the experimental group (EG) – students of the following schools: Kostyantyniv educational complex ‘General education school of I-III degrees’, Kramatorsk educational complex ‘General education school of I-III degrees No. 6’, Kryvyi Rih general education school No. 122. Preparation for the EIA in Mathematics in the classes of the experimental group was carried out according to the method of implementing a system of problems, in which the interdisciplinary connections of Mathematics and Literature are implemented, the problems were developed based on the plot of Bulgakov’s novel ‘The Master and Margarita’.

After the end of the experiment, the final trial test of the secondary school in Mathematics of EC and CG students was conducted to determine the level of their mathematical preparation. To determine the level of knowledge and skills of high school students, the following distribution of points was used, under the official report on the conduct of external examinations in 2021 [10]: 0 points – failed; 1-9 points – elementary level; 10-19 points – average level; 20-34 points is a sufficient level; 35-50 points is a high level, according to the orders of the Ukrainian Center for Evaluation of the Quality of Education [11, 12] (table 2).

Table 2. The results of the trial test of the external examination in Mathematics of high school students of the control and experimental groups.

Level	Number of students			
	EG		CG	
	At the beginning of the experiment	At the end of the experiment	At the beginning of the experiment	At the end of the experiment
Failed (0 points)	2	0	1	0
Elementary (1-9 points)	13	8	11	9
Average (10-19 points)	29	20	27	23
Sufficient (20-34 points)	23	35	22	28
High (35-50 points)	8	12	9	10
In total	75	75	70	70

The results of the tests are presented in figure 1 for the EG and figure 2 for the CG.

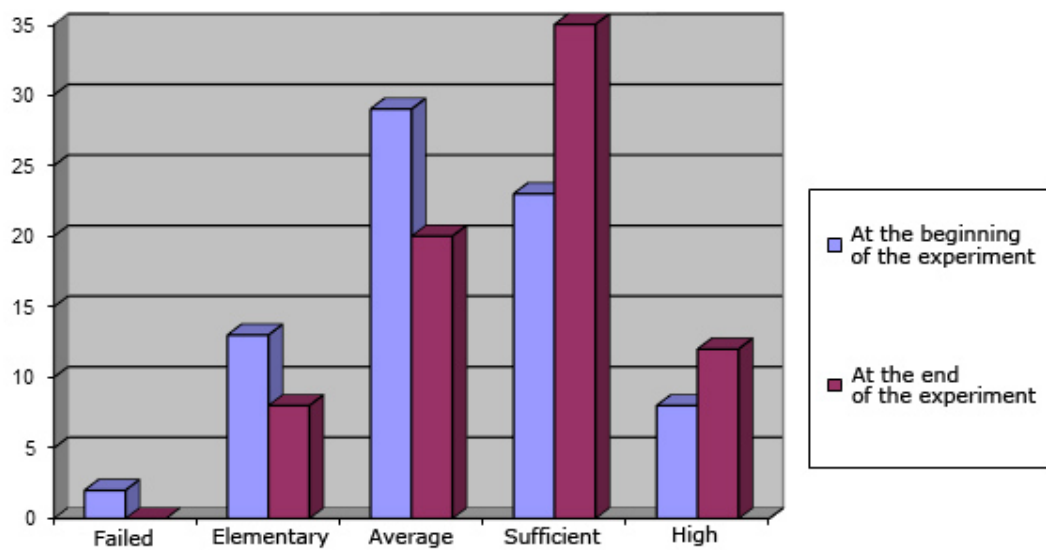


Figure 1. Comparative analysis of the results of the trial test in Mathematics at the beginning and the end of the experiment of high school students of the EG.

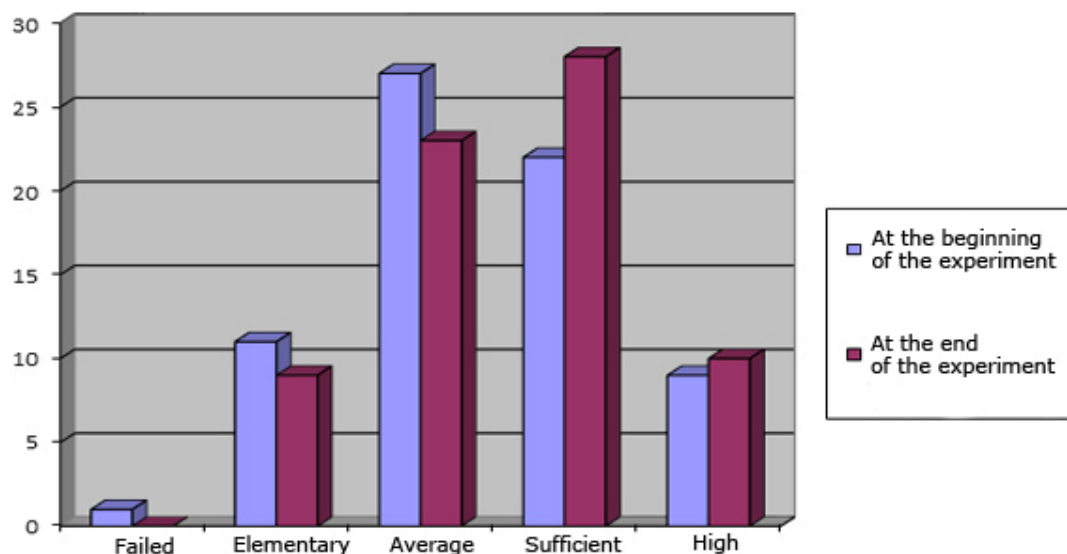


Figure 2. Comparative analysis of the results of the trial test in Mathematics at the beginning and the end of the experiment of high school students of the CG.

The histograms figure 1 and figure 2 show that the level of students' (CG, EG) knowledge and skills have increased. However, in CG the average score increased by 2.4, and in EG – by 5.9, which indicates that the implemented system of problems has a more significant effect on both increasing the motivation of students to study Mathematics and their mathematical preparation.

5. Discussion

The relevance of the development of cross-curricular problems for learning Mathematics to humanitarian students is confirmed by the opinion of Pesakovic et al. that such tasks contribute to the formation of mathematical competence as a key [13].

The works of Furner and Duffy [14, 15], in which the advantages of using Literature in learning Mathematics are defined, such as the development of mathematical thinking, the use of historical, cultural and practical applications, promoting the use of certain mathematical manipulations related to history, ensuring the exchange of experience both for students and for the teacher allowed the authors of this article to make sure of the relevance of developing a system of problems for preparing for the EIA in Mathematics of high school students who study in humanities classes and classes with a creative inclination. Moreover, we support Furner's point of view [16, 17] on the current issue, when it is crucial to interest young people in Mathematics in our high-tech STEM world in which we live [18]. At the scientist's suggestion, mathematical ideas are presented in the context of the story. The results of such use of Literature in learning Mathematics can help reduce Math anxiety and awaken students' interest and confidence in Mathematics and STEM fields.

For students who master Mathematics at the basic level of training, this subject is not a profile, so it is extremely important to motivate them to learn mathematics through the involvement of interdisciplinary problems related to the humanitarian profile of education. This means that it is possible to teach students mathematical modelling while mastering each academic discipline. This opinion is confirmed by the work of Little [19], who investigates the relationship between Mathematics and other sciences and looks for ways so that high school students do not consider mathematics inappropriate, questioning the benefits of studying it.

Arpin [20] advocates the implementation of interdisciplinary connections with benefits both for the educational needs of a specific educational profile and for Mathematics. Toliver [21] assures in his studies that the synergy between Mathematics and Literature should not be too surprising: Literature and Mathematics have many common themes. Both deal with patterns and relationships. There is a natural connection between these two subjects. And this, in turn, emphasizes that the system of problems created by the authors of this article is aimed at the formation of such mathematical skills: gathering information and choosing the appropriate recording and display method; finding regularities in various forms of writing and expressing them in mathematical terms; development of calculation skills when analyzing information.

The idea of creating a system of problems is based on the plot of a well-known Bulgakov novel 'The Master and Margarita'. The same idea is also reflected in the research of Look [22], who analyzes the works of different authors, such as Jules Verne, Anton Chekhov, etc. and offers ideas for further problems that can be reformulated in terms of simple mathematical equations.

All in all, the authors of this article set a goal to develop problems that demonstrate such types of interdisciplinary connections of Mathematics with Literature, such as parallel learning and the application of the method of mathematical modelling. Since Bulgakov's novel 'The Master and Margarita' is studied in the first half of the 11th grade according to the curriculum of the 'Foreign Literature' discipline, and preparation for the external examination and general repetition in Mathematics takes place in the second half, this allowed to demonstrate the method of parallel learning. At the same time, the content of the novel is saturated with a sufficient number of facts, which are presented in numerical form, which in turn allows applying the method of mathematical modelling and using these facts to construct problems of mathematical content. When developing problems, the authors followed the principle of building competence-oriented tasks. According to this principle, the problem contains the so-called 'informational noise' and purely mathematical content. In the proposed system of problems, the mathematical content was built based on numerical data taken from the plot of the novel, and the 'informational noise' was connected with the emotional style of the novel and therefore did not distract students, but

on the contrary, created an interdisciplinary connection between Mathematics and Literature. In this way, the developers of the problems managed to combine the aesthetic sensitivity of Mathematics with the literary sensitivity to words.

The results obtained during the experiment confirm the effectiveness of the influence of interdisciplinary problems both on the motivation of students and on their general and mathematical preparation. This result is consistent with the conclusions of the Interdisciplinary Laboratory of Literature and Mathematics [23], made as a result of a review of the advantages of combining Literature and Mathematics, namely:

- in the sense of general development – helps the student to adapt to different learning styles, and develops their critical and logical thinking;
- in the sense of motivation – attracts students, improving their attitude to Mathematics;
- from the point of view of mathematical preparation – helps the student develop and visualize multiple representations of mathematical concepts, reduces anxiety associated with the study of Mathematics, improves mathematics performance, provides a specific context for understanding Mathematics, helps connect Mathematics with personal experience, develops reasoning, mathematical thinking and ability solve mathematical problems.

6. Conclusions

The comprehensive and multifaceted interdisciplinary connections of Mathematics with other school subjects, in particular the humanities cycle, can become a guide for Humanities students to study the academic discipline of Mathematics, which is not a profile for them. In the study, using the example of the implementation of a system of mathematical problems, in which the interdisciplinary connections of Mathematics and Literature are implemented, the effect on increasing the motivation of humanitarian students to study Mathematics is shown.

The researchers recommend the search for new methodical approaches to the development of problems that contribute to the preparation of students of humanities classes to pass the state final certification in Mathematics in the format of external examinations. Regarding the selection and systematization of interdisciplinary problems, the researchers suggest choosing a system of problems that is developed based on Bulgakov's novel 'The Master and Margarita' and in which the interdisciplinary connections of Mathematics and Literature are realized. Such problems, with their plot and content, on the one hand, interest students, and on the other hand, contribute to their mathematical training.

The effectiveness of the system of problems built on the plot of a literary work depends on several factors: first, a literary work that is interesting to students and already known to them from the school curriculum must be chosen; secondly, it is appropriate to choose a work that allows its plot to create a situation that requires the construction and study of its mathematical model; thirdly, it is important to choose the principle of construction of problems of a certain type, for example, competence or application; and finally, an important factor in the construction of problems is the combination of the aesthetic sensitivity of Mathematics with the literary sensitivity to words.

To implement the proposed system of problems in Mathematics learning, it is recommended to classify the problems according to the sections of Mathematics that correspond to the program of the EIA. In particular, the authors of this article developed a system of problems with an open short answer, which demonstrates such types of interdisciplinary connections between Mathematics and Literature as parallel learning and the application of the mathematical modelling method. For this, the authors of this article used: the method of primary research of the EIA tests in Mathematics of previous years, as well as the method of analysis and selection of the main content lines presented in the external independent assessment in Mathematics. The authors of this article also propose to consider the problems of the system as a toolkit for

measuring the level of preparedness of students of the humanitarian profile to solve typical tasks of the EIA.

The positive results of the implementation of the system of interdisciplinary problems, which were developed based on the plot of a literary work, in the preparation for the EIA of humanitarian students is evidenced by the increase in the level of motivation of students and their mathematical training, which were confirmed during the experiment.

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