

## School mathematics education in Ukraine: challenges and prospects

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Education in Ukraine, particularly mathematics, underwent some transformations during the years of independence. Orientation to the European educational space encourages the development of new standards and school curricula that meet today's demands (practically oriented learning, conceptual understanding of mathematics, research-based learning etc.). At the same time, mathematics school education faces many problems, including a decrease in the level of teaching of mathematical subjects, the inconsistency of the education content with the requirements of today, the low quality of textbooks, and the lack of appropriate conditions for providing specialised mathematics education. The report presents the research results to identify pupils' mathematical literacy and the level of STEM education. A study of more than 3,000 pupils revealed typical knowledge gaps caused by distance learning during the Covid-19 pandemic. To overcome the identified problems, particular methodical recommendations were developed.

**Keywords: mathematics education in Ukraine; STEM education; mathematical literacy.**

### Introduction

Ukraine has over 14,800 secondary schools, with 4.2 million students and 441,000 teachers. Currently, Ukraine is undergoing a gradual transition to 12-year school education to approach European standards. The 11-year school in Europe stayed only in Ukraine, Russia and Belarus. As practice shows, this model does not satisfy the needs of modern society, primarily due to the excessive overloading of pupils with learning material.

In Ukraine, the following levels of general secondary education are provided: primary – 4 years of study, basic level – 5 years, senior professional school – 3 years. According to this distribution, pupils after the 9th grade can enter college. Upon its graduation, they receive a junior bachelor's degree.

A senior 3-year specialised school with two types of profiles is also planned: academic and professional. The academic profile is aimed at continuing education at the university. The introduction of 12-year secondary education will make it possible to shorten university studies at the bachelor's level to 3 years; now, it is four years. The professional profile of secondary education provides for obtaining the first profession upon graduation and the opportunity to enter the labour market. The training of pupils according to the new twelve-year general secondary learning programs was introduced during 2018-2022.

*What are the main problems of school education, mainly mathematics education, in Ukraine?*

1. During Covid-19 and martial law, distance learning is mainly implemented. More than 500 000 pupils (about 12% of the total) live abroad now and continue to study online.

2. Insufficient financing of the educational sector, outdated school equipment and computers, and lack of high-speed Internet.
3. Needs to be a more qualified level of teaching staff. University graduates do not want to work in schools because of low wages and the declining prestige of the teaching profession.
4. Many children lack interest in learning. So, about 42% of teachers believe that less than half of the pupils in the class are interested in mathematics.
5. Outdated teaching methods, teaching mathematics content needs to connect with today's conditions.

What is the solution to the problems? It is the "The New Ukrainian School" reform, implemented since the beginning of 2017 (The New Ukrainian School, 2017). Its main goal is to create a school where it will be pleasant to study and give pupils not only knowledge, as it happens now, and the ability to apply this knowledge in everyday life.

### ***What is changing for pupils?***

Instead of learning facts and concepts, pupils acquire competence. The list of competencies was created considering the "Council Recommendation of 22 May 2018 on key competences for lifelong learning" and includes mathematical competence (Council Recommendation of 22 May 2018 on key competences for lifelong learning, 2018).

### ***What is changing for teachers?***

The goal of the reform is to promote the professional and personal growth of teachers and to increase their social status. The teacher gets the freedom of action - to choose learning materials, improvise and experiment. The Ministry of Education and Science of Ukraine offers standard curricula, but any teacher or author group can supplement or create their own. The teacher is limited only by the State Standard. This document outlines the outcomes: what pupils should know and be able to do when they have completed a particular stage of learning. But, how to reach these results the teacher will determine himself.

### **Modern reforms of school mathematics education**

The flagship of the reforms is the implementation of the Concept for the Development of Science and Mathematics (or STEM Education), which is focused on the following:

- The transition from a knowledge-oriented learning paradigm to a competency-based one, forming mathematical and critical key competencies necessary for successful self-realisation in society.
- Reorientation of the content of education on the individual to ensure the active cognitive position of a pupil.
- Organisation of training based on taking into account the experience of the pupil's interaction with the surrounding world.
- The focus of learning is on realising abilities, the intellectual, spiritual and creative potential of a young person.
- Development of sustainable mechanisms of self-learning, self-education and self-development (Concept for the Development of Science and Mathematics, 2020).

The most urgent problem of mathematics education in a 12-year school is its content selection. The traditional content of teaching mathematics, composed for

decades since the time of the Soviet Union, weakly took into account changes in engineering, production, and digital technologies.

So, special cross-cutting lines of key competencies are represented in grades 5-9 curricula.

The cross-cutting line "Environmental safety and sustainable development" is implemented in the mathematics course, mainly through tasks with actual data on using natural resources, their preservation and multiplication. The analysis of these data contributes to the development of a caring attitude towards the environment, and ecology, the formation of critical thinking, the ability to solve problems, and the essential evaluate the prospects for the development of the environment and humans. Regarding this line, percentage calculations, functions, and elements of statistics have an important place.

Implementing the cross-cutting line of "Civil responsibility" will contribute to forming a responsible member of the community and society who understands the principles and mechanisms of society's functioning. This cross-cutting line is mastered mainly through collective activities (research works, the group works, projects, etc.), which combine mathematics with other learning courses and develop in pupils a readiness for cooperation and tolerance for various ways of activity and thoughts. For example, percentage calculations and elements of statistics are connected with this line.

The cross-cutting line "Health and safety" task is forming the pupil as an emotionally stable member of society, capable of leading a healthy lifestyle and creating a safe environment around him. This cross-cutting line in the mathematics course is realised through problems with real-world safety and health data (text math problems related to the traffic environment, pedestrian and vehicular traffic. When studying the basics of mathematical statistics, it is worth paying attention to the issues associated with risks to life and health. Solving problems found with the "Eureka effect", considering beautiful geometric structures, searching for optimal methods of solving problems, etc., can cause a lot of joyful emotions in pupils.

The cross-cutting line "Entrepreneurship and financial literacy" is related to solving practical problems associated with planning economic activity and objective assessment of one's capabilities, planning a family budget, forming an economical attitude to natural resources. It is implemented during the study of percentage calculations, equations and functions.

The study results on the level of mathematical literacy of 15-year-old students (comparison with the results of the PISA study)

The purpose of the research is to analyse the results of diagnostics on the ability of pupils to apply the acquired knowledge of mathematics to solve practical problems and to develop recommendations for improving the quality of mathematics education at school.

The study was conducted in 2021, shortly before the start of the war in Ukraine. The study's respondents were 1,849 pupils of schools in Kyiv. A total of 292 schools were involved. The respondents were 15-year-old pupils. In most countries, pupils graduate from basic school at this age and face the choice of a profession and, in general, their future life path.

The study aimed not to determine the pupils' mastery of the school curriculum. Their ability to use math knowledge, skills and abilities acquired at school to overcome real-life difficulties and challenges was evaluated. This ability consists of a clear understanding and awareness of the role of mathematical knowledge in the

modern world, the ability to explain science and scientific phenomena, make reasonable conclusions about them, understand the impact of science and technologies on improving the material, intellectual and cultural environment.

In this aspect, the study coincides with the PISA International Student Assessment Program. The results of PISA in Ukraine in 2018 confirmed the need to modernise the mathematics education of pupils in secondary education institutions.

We created a test that consisted of 10 tasks for 20 minutes and included the following topics: "Numbers and expressions", "Equations and inequalities", "Functions", "Triangles, quadrilaterals, circles", and "Vectors and coordinates". Pupils were requested to complete tasks for the previous class at four difficulty levels.

The ability of pupils to apply their knowledge of mathematics to solve practical problems according to four levels has been established:

- Elementary level – 23.7% of pupils.
- Basic level – 35.8% of pupils.
- Upper-intermediate level – 30.4% of pupils.
- Advanced level – **10.1% of pupils.**

These data are comparable to the results of the assessment of the knowledge of Ukrainian schoolchildren in the International Study of the Quality of Education PISA-2018.

According to the study results, on average, each pupil correctly solved half of the tasks of a practically oriented nature, which can be attributed to the intermediate or basic level of ability.

Analyse the success of mathematical tasks. The study found that the best pupils solved problems on the following topics: "Numbers and expressions. Numerical sets", "Functions. Formula", "Coordinates and vectors. Coordinates of the point". The range of correct answers ranged from 84.2% to 90.4%. With the help of these tasks with practical content-tested knowledge of numerical sets, the ability to correlate the desired number with the numerical set to which it belongs, to express the formula of the relationship between two variables, and to determine the coordinates of a point. Analyse some test tasks (Figs. 1, 2).

**Task 1.** What is the number of participants in a video conference?

A  $\sqrt{160}$

B  $\frac{200}{3}$

C 18

D -15

Figure 1. Test task 1.

Task 1 statistics show that 8.4% of respondents did not understand the conditions of the task and believed that the number of participants in the video conference could be non-integer or negative. To determine the correct answer, it was necessary to find out that the number 160 is not a square of a natural number and that the number 200 is not divisible by 3.

**Task 2.** 51 jars with sauces and jams were packed in gift sets, each containing either three jars with sauces (x sets) or four jars with jams.



Specify the correct equality.

- A  $3y + 4x = 51$
- B  $3x + 4y = 51$
- C  $\frac{x}{3} + \frac{y}{3} = 51$
- D  $12xy = 51$

Figure 2. Test task 2.

Building a mathematical model (task 2) is an essential mathematical competence in solving text problems. One-tenth of the participants did not compose a letter expression with variables determining the number of food cans. An important element was the drawing, which visualised the condition of the task and facilitated its implementation.

Quite successfully students coped with the topic: "Numbers and expressions. Text tasks" and "Functions. Function schedule". The range of correct answers is from 63.2% to 75.9% (Fig. 3).

**Task 8.** Tourists raft down the Tisza River on inflatable boats without engines, using oars only to avoid obstacles. The length of the rafting route is 6 km. The speed of the Tisza along the entire route is 1.5 km / h. How many hours will tourists spend rafting on the river?

Figure 3. Test task 8.

With the help of task 8, the formation of such subject competence as the ability to solve a text problem in an arithmetic way was tested. The task was to understand that an inflatable boat moves on a river at the speed of its flow and to determine the number of hours tourists spend rafting on the river, using the formula for the length of the route from rafting time and boat speed. Note that 30% of participants did not cope with this task.

The next step of the research was the search and substantiation of the factors that influence the quality of science and mathematics education of pupils.

The following external and internal factors were selected for analysis (according to pupils as participants in the learning process):

1. Type of school institution. Lyceum pupils were the best among other pupils (on average, each pupils solved 52.0% of the tasks), and secondary school pupil solved 43.0%). The study's results confirmed the data of the PISA study for Ukraine - a significant gap between the average results of pupils of public schools and individual specialised educational institutions.
2. Profiles of the class and the school institution. The tasks were solved better by the science and mathematical profile class pupils.
3. Material and technical and educational, and methodological support. The highest results were obtained by pupils of those schools where, according to the teachers, modern equipment and necessary materials are available for quality implementation of the learning process, and the libraries are equipped with current textbooks.

4. Distance learning. Pupils of those schools where, according to the teachers, all pupils are covered by distance learning received the highest points in testing.
5. Professional level of the teacher. A pattern was established: pupils who liked the teacher got higher test scores. The analysis of the statistical portrait of mathematics teachers in Kyiv schools makes the following facts: the schools are mainly staffed by women over 50 years old, they have a higher teaching category, more than 21 years of experience, more than 11 years of teaching at the same school and have an additional workload (class management, office management, public work, etc.)
6. Motivation of pupils. Among the essential factors that affect the quality of education, pupil motivation and its components are highlighted: pupils' attention to studying mathematics because it will be needed for university education; pupils' attention to studying mathematics because they like it.
7. Practice-oriented content of the training. In most cases, those pupils who feel the importance of mathematics for solving practical problems received higher results.

To the study results, recommendations were developed for improving the quality of mathematics education at school in the context of implementing the "New Ukrainian School" reform.

## Conclusions

We have prepared recommendations (Grinevich, 2021). I briefly demonstrate some of them as examples.

1. Increasing the attention of teachers to the study of academic topics that caused the most significant difficulties for pupils in the testing process.
2. Introduction of interactive learning technologies, use of digital tools for demonstrations, and popularisation of group work to increase pupils' interest in mathematics.
3. Active use of interdisciplinary practice-oriented tasks in the learning process.
4. Ensuring **the development of the internal system of education quality.**

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