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Introducing the latest teaching and educational development practices in mathematics: the experience of EU countries

Запровадження новітніх практик викладання та розвиток освітнього процесу у галузі математики: досвід країн ЄС

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Abstract

The purpose of this work was to investigate the qualitative implementation and the possibility of use in the educational context of Ukraine. For this work, the author invited five groups (a total of 169 students of different genders). The second was a conversation with the teachers about the atmosphere in the classroom, the difficulty of the learning process, and the results. The study showed the weakness and small effectiveness of the old teaching methods (control group) and elementary explanatory online meetings.

Keywords: mathematics, pedagogy, digitalization, flipped classroom, education.

Анотація

Мета цієї роботи полягала у дослідженні якості впровадження новітніх практик викладання математики та можливості їх використання в Україні. Для цієї роботи було запрошено п'ять групи студентів та студенток 3 курсу (всього 169 студентів) педагогічних спеціальностей. Упродовж трьох місяців, вони вивчали математику по новим методикам. Задля отримання результатів, використовується метод тестування (перевірка поточних та кінцевих знань студентів), статистичного аналізу та бесіда (з викладачами). Результати дослідження представлені у формі відсоткового співвідношення між оцінками до та після експерименту. Дослідження показало слабкість старих методів навчання (контрольна група) і онлайн-зустрічей. Продемонструвало велику перевагу STEAMосвіти, та впровадження «електронних портфоліо».

Ключові слова: математика, педагогіка, цифровізація, перевернутий клас, освіта.

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Introduction

Mathematics is one of the oldest sciences in our world. Since ancient times, it has become a universal language for the whole world, a method for the development of human logical thinking, and a way for scientific and technical development. Studying mathematics at school and in high schools gives pupils and students not only the acquisition of specialized knowledge but also the development of intellect and consistent thinking. Like any subject (humanities, natural or technical), the teaching of mathematics is being redefined, changed, and transformed through sociocultural conditions.

Thus, with the rapid development of globalization and active scientific and technological progress, we are now witnessing the digitalization of the entire world, which has also affected the sphere of education. So, in 2018, at the level of the French Ministry, questions about electronic textbooks, electronic portfolios, the introduction of presentations and video lectures, the prospects of introducing distance learning, the use of special computer programs, and many other issues are raised (Gueudet et al., 2021). If discussions of the ideas of digitalization of education have been longstanding and mostly theoretical and only sometimes practical, then with the arrival of the total pandemic covid-19 and forced lockdowns, distance education is reaching an urgent practical level.

Most countries of the world and Europe have been forced to introduce "distance learning" (Weinhandl et al., 2021) tearing students away from the collective with peers, from the teacher, and with an apparent shift in the emphasis of learning to independent work. For example, France proposed the formation of students' "autonomous" learning ability (Gueudet et al., 2021). The transition to distance learning requires an active reorientation and change in teaching methods on the part of teachers. Therefore, digitalization requires schools, universities, and other educational institutions: logistical support, new teaching methodology, and active communication between student and teacher.

Research Problem

Like most countries in the world, Ukraine is trying to maintain the level of quality education, but old teaching methods are losing their relevance and it is necessary to change approaches. The model for the introduction of the latest practices in education are the countries of

the European Union, so to analyze their experience and place it in Ukrainian conditions in the future gives a new impetus to the development of modern science, focused on quality standards.

Research Aim and Research Questions

Our study aims to analyze the latest methods of teaching mathematics (on the example of the European Union countries) in Ukrainian schools, establishing their effectiveness and further development. The stated theme and purpose of the study led to the following tasks: to analyze the latest methods of teaching mathematics in the European Union, to form criteria for sampling subjects, to distribute groups into "control" and "experimental", to conduct three control and one final test, to interview teachers and through statistical analysis, comparative and hermeneutic practices to draw conclusions.

Materials and methods

General Background

For this study, we selected five 8th graders from different schools. The students were not mixed among themselves. By leaving students in a comfortable and familiar environment, we do not add to the stress of entering a new environment by avoiding the need for adaptive time. In the case of independent or group work, students already know each other and will be able to ask for help from each other more quickly, as well as be comfortable with being assigned to groups (for example, as with the STEAM system).

Of the five groups, one of them was taught using standard methods of teaching mathematics (the control class), and the others with the latest technology were experimental. Thus, one group, GP-A, was taught using the "checked group" concept. Group GP-B, in distance education, actively used online meetings with the teacher to discuss questions about the material. Group GP-B studied with the introduction of individual "electronic portfolios". Group GP-G studied "STEAM education".

The number of students in the group (on average) was 25-30 people. The total number of people was 169. Gender number: 55% - girls and 45% - guys. Material and technical base: all students were equipped with technical means (computers) and the Internet. Most of the students come from the middle class and have good living conditions

and family support. Therefore, the social atmosphere should not have had a large and negative impact.

Instrument and Procedures

The empirical methods that we used in the research we can refer to: testing and conversation. The experiment was conducted for three months and included two stages. The first was testing to determine the assessment and quality of the students' knowledge of mathematics. During the three months, we analyzed three current tests and one final test that required students to apply all the knowledge they had acquired. The second phase was a conversation with the teachers. Thirty minutes were allotted to each person. All interviews were transcribed and analyzed. Conducting the second phase provided a more realistic understanding of the implementation of the latest mathematics teaching practices. First, the teachers knew their classrooms. Second, the teachers were able to compare their teaching experiences with the old and new methods.

Data Analysis

The results were analyzed using the “statistical” method of data processing. It is necessary to demonstrate and compare the quality of the mathematics knowledge obtained with the implementation of the latest teaching practices. The audio files from the teacher interviews were transcribed and analyzed using comparative and hermeneutical methods. Questions focused on classroom atmosphere, difficulties in the introduction, student motivation, and visible results.

Literary review

The latest technologies for teaching mathematics have a wealth of theoretical and practical research (e.g., that has taken place through questionnaires) (Weinhandl et al., 2021). Large universities in Europe are conducting a variety of studies to improve the learning process, create a comfortable environment, and identify the best teaching method. In collecting data, we found that the learning process and the teaching of mathematics, in particular, during the covid-19 pandemic was addressed by (Ní Fhloinn & Fitzmaurice, 2021). Pepin et al. (2017) have joined in the analysis of the remote presentation of mathematics. The research in the implementation of STEAM education in the Spanish experience was done by (Diego-Mantecon et al., 2021), (Diego-Mantecon,

Prodromou, Lavicza, Blanco, Ortiz-Laso, 2019). The ideas of integrating programming to mathematics have been addressed by (Bråting & Kilhamn, 2021). Epistemologies of learning and issues of inclusion have been addressed by: (Hudson, 2018; Hudson, 2019). Practices of the “flipped classroom” have been addressed by: (Feudel & Fehlinger, 2019), Weinhandl et al. (2018).

Also, in their paper Weinhandl et al. (2018) considered the topic of “e-portfolio”. The problem of teaching mathematics in Austria was addressed by Kadunz & Zudini (2021). Additional information on the educational process in Sweden we took from the official government source: Swedish National Agency of Education (Swedish National Agency of Education, 2018). The latest technologies in education in France and the concepts of student autonomy have been dealt with by (Gueudet et al., 2021). The study of the learning process, using the comparative method, applying it in Europe and Japan, was done by: Asami-Johansson et al. (2019).

Results

The latest technology in mathematics

Looking at the experience of the European Union countries in changing education and in the field of mathematics, the introduction of the latest practices, the rethinking of the received experience, we see that many countries are focused on the digitalization of being. The pandemic of Covid-19 forced the introduction of emergency measures in the educational process, which gave impetus to the development of theoretical and practical pedagogy. So, studies on the effectiveness of teaching mathematics online, the availability of material and technical facilities in schools, or the conduct and effectiveness of distance learning appeared.

We begin our consideration of new practices in mathematics teaching by identifying them in distance learning. The University of Ireland, led by researchers Ní Fhloinn & Fitzmaurice (2021), conducted online surveys of mathematics teaching in the early months of the pandemic. They received active feedback from teaching subjects who had directly experienced the changes. Evaluations and recommendations covered a variety of areas within distance learning. Here are a few of them: First, technologies that connect all subjects of learning should be uncomplicated (this recommendation came from their practical use). It should be

remembered that “students must adapt to this new way of doing things”. Comfortable use of learning platforms is a psychological comfort for students and learners. Second, the researchers came to a consensus on the need for “dialogue” between all actors in the learning process because students need psychological and emotional support. After conducting research, it turned out that students lacked live communication. One method of supporting the student is the introduction of an “online chat” or “discussion forum”. A study by Ní Fhloinn & Fitzmaurice (2021) noted the convenience of communication when teachers can post at any time, students can engage in streaming on YouTube, where “students can comment and ask questions via email or chat”. Second, the researchers came to a consensus on the need for “dialogue” between all actors in the learning process because students need psychological and emotional support. After conducting research, it turned out that students lacked live communication. One method of supporting the student is the introduction of an “online chat” or “discussion forum”. A study by Fhloinnhttps & Fitzmaurice (2021) noted the convenience of communication when teachers can post at any time, students can engage in streaming on YouTube, where “students can comment and ask questions via email or chat”.

Weinhandl et al. (2018) also spoke of the central role of the “social dimension” in learning mathematics, examining the experiences of Austrian schools that, with the onset of the pandemic, were open only temporarily, to receive homeschooling materials. Exceptions were small classes for students whose parents were classified as essential workers (e.g., health care workers, grocery stores, or public transportation workers) and who could not physically support children in distance learning.

Weinhandl et al. (2018) draws attention to the disadvantages of online classes. They concern both technical problems and the moral state of students. It is believed that in a bad in tension atmosphere there is detachment from the learning process, a lack of motivation in acquiring this knowledge. Because motivation and emotion are critical to the success of online mathematics instruction, special attention should be given to the community and social support when planning and conducting online instruction (Weinhandl et al., 2018).

Therefore, one practice is the introduction of audio-visual “online meetings” to discuss the material.

E-portfolio

Another effective innovation for learning mathematics that combines pedagogy and technology is the creation of an “e-portfolio” for each student in each individual subject.

An e-portfolio is an electronic document that demonstrates a student's work and progress in a particular subject. According to Weinhandl et al. (2018), working with an “e-portfolio” helps the student make connections between mathematics and the real world, develop and demonstrate learning outcomes in mathematics, and show individual mathematics topics of interest to the student. Teachers should also benefit from the use of electronic portfolios. One of the benefits of “e-portfolios in teaching mathematics for teachers is feedback from students” (Weinhandl et al., 2018). With knowledge from students' “E” portfolios (as it is also called), a teacher can not only help with a particular problem in mathematics but also change teaching methods, coordinate a student's views in the right direction, recommend literature and assignments for the student's interests.

Weinhandl et al. (2018) analyzed the effects of e-portfolios. The authors analyzed the relationship and effects of portfolios on students' mathematical achievement. The authors were able to establish in their study that when students learn mathematics through the use of electronic portfolios, they can achieve better learning outcomes in “higher-order thinking tasks”. In addition, it is illustrated that by changing the assessment processes in e-portfolios (from pointing out weaknesses to pointing out students' strengths), metacognitive skills such as reflection can also be developed.

Research to analyze e-portfolios shows positive results on the mathematics research side. “When taught with hands-on, student-centered approaches to mathematics instruction, such as the use of electronic portfolios, can be fruitful. According to Weber, demonstrating in his study that students who received experimental instruction were able to develop a deep understanding of trigonometric functions” (Weinhandl, 2021).

The practice of the “flipped” classroom

“Flipped” mathematics teaching finds its place in European countries (particularly Germany and Austria) as an alternative to the classical model of teaching, in which students first mastered new material in the classroom in a lesson.

The traditional scheme of teaching is very well known to us: the teacher comes to the class, tells the new material, simultaneously puts formulas, theorems, etc. on the board, commenting on the new material at the same time. It is believed that the student needs intensive intellectual work to master the new material (Weinhandl et al., 2018). The student does several things at the moment of presenting new material: listening, taking notes, trying to understand. "Thus, to understand the content, many students will need intensive post-lesson processing based on their notes. However, students often do not carefully work through lectures after class. On the other hand, they often do not write down the lecturer's oral explanations necessary to understand the formal content of the lecture" (Feudel & Fehlinger, 2021).

We have found and analyzed two kinds of "flipped method". The first method is a certain inverted approach to teaching mathematics. It was developed by Weinhandl, Lavicza, Süß-Stepancik. The second is the concept of the "flipped classroom" considered by Feudel, Fehlinger (Feudel & Fehlinger, 2021). It should be noted that at the heart of the two approaches is the flipping of the responsibilities of the subjects of learning. At a certain point, the student assumes the "function" of the teacher, and the teacher takes a back seat. He or she becomes a guide in the world of mathematics. Weinhandl et al. (2018) believe that group learning spaces can be turned into dynamic, interactive learning environments. Direct instruction or individual feedback (concerning the material) is given individually in individual learning spaces rather than as a whole. The second option of "flipping through" is a fully flipped classroom. The meaning of this practice is to familiarize in advance with the new material, and the teacher's role is to explain incomprehensible points, add comments, etc. That is, the teacher's job is only to help him understand it. By the way, we can notice that the practice of flipped learning has a correlation with the idea of self-organization (autonomy), actively implemented in France.

Practice combining mathematics and programming

Another practice in teaching mathematics is to combine/include/partially include it with programming. Denmark and Sweden have had this experience and over the last 5-6 years have started to include programming skills in the "basics". The relevance of this method is also based on scientific and technological development. "In particular, programming is

often emphasized as a pedagogical tool in developing students' computational thinking" (Bråting & Kilhamn, 2021). Although the question of the obviousness of incorporating programming into mathematics still remains, Finland and Sweden have integrated with each other.

The pluralism of opinion on the inclusion of programming in mathematics has led to new subjects that "fully integrate" the two branches. Thus, in England and Denmark, programming has become part of the new school subjects Computing and Understanding Technology (Bråting & Kilhamn, 2021).

STEAM education

The introduction of STEAM education (S - science, T - technology, E - engineering, A - art, and M - mathematics), which was originally created and developed in the USA, deserves special attention. There have long been opinions in society that STEAM education competes with classical education and is capable of supplanting it in the future.

STEAM is an education program that incorporates the interdisciplinarity of different areas of knowledge. The old education showed that the modern child is not able to fully connect the knowledge of different disciplines, and this is an indicator of logical thinking, the ability to analyze knowledge and find answers to various questions and problems. STEAM offers a solution to these problems. At the heart of the new education is the idea of a "universal" person. And the learning process is built on "solving certain problems".

Diego-Mantecon et al. (2021) in their study tried to analyze and evaluate STEAM education together with project-based learning on the learning side of mathematics. To begin with, the researchers noted that mathematics teachers avoided interdisciplinary projects in which it was difficult to do school mathematics, while teachers outside the field (outside mathematics) tended to overlook mathematics in interdisciplinary projects. STEAM education allows students to solve specific problems and create specific projects that excite them. Thus, students will be required to use a variety of knowledge to implement their projects. As the researchers point out, in such an environment, mathematics (if challenging) can be facilitated by the teacher himself and adjusted to the student's current level of knowledge. Diego-Mantecon et al. (2019): "Projects that emphasized engineering

and technology components helped students with low average success in mathematics develop a practical sense of the discipline's applicability and positive beliefs about learning it".

Practice student automation

The French government is launching a national curriculum aimed at developing the idea of "self-management" and "autonomy" for students, as well as the introduction of the latest technology, such as the introduction of a "digital plan for schools" (Gueudet et al., 2021). There are difficulties with the introduction of technology because of the rich spectrum of understanding of this field. Gueudet et al. (2021) identify two categories in their study. Digital technologies can be subject-oriented (e.g., dynamic geometry software) or generic (e.g., online collaborative writing tools) Gueudet et al. (2021). The authors see a direct correlation between technology and offline mathematics learning.

Gueudet et al. (2021) consider and distinguish two levels of mathematical autonomy. The first is the mobilization of previously acquired knowledge, an indicator of which will be the rapidity of their use. The second is the discovery of new knowledge. The source for obtaining such knowledge will be the independent solution of certain problems, tasks, etc. The authors conclude and distinguish "autonomy" into three categories: transversal autonomy, autonomous mobilization of familiar mathematical knowledge, and autonomous development of new mathematical knowledge (Gueudet et al., 2021). Students can use different sites and digital resources, which will provide new knowledge and mobilize already acquired knowledge. Certain environments or software (e.g., dynamic geometry systems) can allow students to formulate and test hypotheses and facilitate the "autonomous development of new mathematical knowledge" (Gueudet et al., 2021).

Together with France, Austria has joined France in introducing technology into the study of mathematics. The years 2021/2022 were proclaimed the years of digitalization. It should be noted right away that the success of this experience still depends on the level of development of the country. Because Austria noted the fact that all students who will enter school will have electronic media for learning, as well as that there will be quality logistical support for all schools. Kadunz & Zudini (2021) tried to investigate and find the problems that mathematics teachers might have with the introduction of digitalization. "Teachers in our study have high expectations for repeating and deepening new content outside the classroom through new technology" Kadunz & Zudini (2021). In addition to "digitalization," we see how the Austrian government is also emphasizing students' independent learning of the material. Digital technology makes it possible to retrieve and repeat material, "pause" videos, and disassemble unclear points. The idea of "accessibility" of learning from the use of technology (as exemplified in many European countries) is befalling all new mathematics teaching practices.

In our study, we will use and analyze all proposed techniques except programming (as an element integrated into the process of learning mathematics). Even though Ukrainian schools are now actively studying computer science in the lower grades, it leaves much to be desired in practical implementation. The new concept of education is not yet expected to introduce new subjects like "Computer Science" and "Understanding Technology". For lack of such a base, we did not include it in our study.

Results

For accurate results of the study at the beginning of the experiment, we analyzed the current state of knowledge in mathematics (Table 1).

Table 1.
The current state of knowledge in mathematics.

| Group name | GP (control) | GP-A (flipped class) | GP-B (online support) | GP-C (e-portfolio) | GP-D (STEAM) |
|--------------------|--------------|----------------------|-----------------------|--------------------|--------------|
| Number of students | 28 | 30 | 30 | 27 | 29 |
| Average score | 8.59 | 9.10 | 8 | 9 | 8.70 |

After three months in the experimental groups and control tests (Table 2), we came to the following results:

Table 2.
Results three months in the experimental classes and control tests.

| Class | GP | GP-A | GP-B | GP-C | GP-D |
|-------------|-------|-------|-------|------|------|
| Control 1 | 8.59 | 9.15 | 8 | 9.10 | 9 |
| Control 2 | 8.59 | 9.20 | 8 | 9.20 | 9.10 |
| Control 3 | 8.70 | 9.30 | 8.05 | 9.30 | 9.20 |
| Final score | 8.75 | 9.35 | 8.10 | 9.45 | 9.25 |
| quality % | 1.86% | 2.74% | 1.25% | 5% | 6.3% |

The results of the control class (GP) did not change significantly. Their results improved by 1.86%. Compared to it, conducting additional “online meetings” (GP-B) during the pandemic also did not give significant results - 1.25%. The teacher noticed children's disinterest, or because of the shame of “not knowing something”. Sometimes the teacher's responses were not enough. Next in the results is the introduction of the flipped classroom - 2.74%, which can be conducted in two formats “online” and “offline”. Grades GP-B and GP-G had the most successful result. Due to the introduction of electronic portfolios and interdisciplinarity of STEAM education, teachers noted that when communicating with students, it was noticed that they were interested and active in the lesson. Analyzing the statistical results, we can notice that this was reflected in the level of understanding of the material as well. The average scores of the experimental classes were higher than the average scores of the control class.

Discussion

The results of the study demonstrate Ukraine's readiness to implement the latest practices in mathematics teaching, considering digitalization and the development of student autonomy. Such practices well support the concept of the “New Ukrainian School,” which aims to form modern people, with an interdisciplinary approach and critical thinking about the world. Such a path in education will make the knowledge of Ukrainian students on a par with that of European students.

Analysis of the data shows that practices based on a creative and project-based component yield faster results than other proposed practices. We can assume that in STEAM education the teacher can adjust the curriculum and adjust it to the projects of his students. And according to the practice of “online meetings,” students “go along” with the plan, just as they would in a flipped classroom. In addition to the speed of mastery, quality is key. High quality in STEAM education and e-portfolio can depend on student

motivation. The greater the interest and motivation - the better the student's mastery of new knowledge and skills. By developing their own project, the student is not only more interested but also takes the knowledge they need and masters it with a special effort.

We must assume our work that perhaps high school and university students will have higher scores in the “classical” model of learning, online meetings, and flipped classroom because of their ability to self-organize, self-control, and prior knowledge. Still, creative tasks always attract more attention than classical and sequential learning models.

Conclusions

Examining the topic of the introduction of new practices and development of the educational process in mathematics, based on the experience of the European Union (France, Austria, Germany, Sweden, Denmark, Finland, Spain) and analyzing their activities on the effectiveness in Ukraine, we can make the following conclusions:

First, the development and implementation of the latest practices in education depend on the scientific and technological development of the world and its digitalization. All countries in Europe are directing their educational policies so as to educate students in the direction of digitalization (as an inevitable stage in the development of the planet), with analytical and critical thinking, autonomy, and autonomy to learn. Trying to pay attention to each student (guiding him), to improve the quality of knowledge, given the comfort of the learning environment and personal interests during learning.

Third, the classical training model has outlived its usefulness in today's Ukrainian realities.

Fourth, online meetings and the concept of a flipped classroom do not provide a meaningful effect and quality result.

Fifth, STEAM education together with project-based activities (primarily liked and developed by students themselves) improves the quality of mathematical learning. This effect is made possible by not trivializing a particular topic but working through it in a specific project in relationship to other disciplines. Thus, students develop analytical thinking and a quality understanding of mathematics in practice. If we look at the implementation of “e-portfolios,” we also see the main component is the student's interest, the demonstration of their own results and skills.

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