

PAPER • OPEN ACCESS

Role and place of Informatics in the training of future teachers of mathematics

To cite this article: N S Ponomareva 2021 *J. Phys.: Conf. Ser.* **1840** 012035

View the [article online](#) for updates and enhancements.



240th ECS Meeting ORLANDO, FL

Orange County Convention Center Oct 10-14, 2021



Abstract submission due: April 9

SUBMIT NOW

Role and place of Informatics in the training of future teachers of mathematics

N S Ponomareva^{1,2}

¹ H. S. Skovoroda Kharkiv National Pedagogical University, 29 Alchevskyyh Str., Kharkiv, 61002, Ukraine

² Kryvyi Rih State Pedagogical University, 54 Gagarin Ave., Kryvyi Rih, 50086, Ukraine

E-mail: ponomareva.itstep@gmail.com

Abstract. The announcement of the 2020/2021 academic year as the Year of Mathematical Education in Ukraine and the adoption of the Concept for the Development of Natural and Mathematical Education (STEM-education) until 2027 were a response to the systemic crisis of mathematical training in general secondary education and training of mathematics teachers in Ukraine. The World focus on the integration of natural and mathematics, informatical and engineering education requires rethinking of the role and place of Informatics as a science, as a study discipline and as a basis of computer engineering in training future mathematics teachers. Nowadays, the teacher of mathematics should be capable for effective professional activity in a rapidly changing technology, educational paradigms and catastrophic educational disruptions, such as the current COVID-19 pandemic.

1. Introduction

The Law of Ukraine “On Basic Principles of Information Society Development in Ukraine for 2007-2015” defines the main strategic goal of information society development in Ukraine as the creation of an education system focused on the use of the latest ICT in the formation of a fully developed personality [19]. “Strategy for the development of the information society in Ukraine” [3] identifies a number of priority measures aimed at implementation of this strategic goal for improving the educational process, accessibility and efficiency of education: development of informational educational environment in the system of general secondary and higher education; creation of an information system to support the educational process; creation of a distance learning system with the effective use of information and communication technologies at all educational levels of all forms of education; development of methodological support for the use of computer technology in teaching of every disciplines; improvement of curricula, etc.

The State National Program “Education” (“Ukraine of the XXI Century”) [2] among the priority areas of education reform identifies, in particular, achieving a qualitatively new level in the study of mathematics. There are assumed the optimal combination of humanitarian, natural and mathematical components of education; widespread use of new pedagogical and information technologies with appropriate scientific and pedagogical, methodological and information support.

Decree of the President of Ukraine “On declaring the 2020/2021 academic year the Year of Mathematical Education in Ukraine” is directed at the creation of conditions for equal access to modern high-quality mathematics education and ensuring a modern level of teaching mathematics. Effective



teaching technologies should be based on best domestic and international practices [14].

Thus, there is a socially determined and legally justified need to improve the training quality for future mathematics teachers. One of the main components of this training is Informatics. So, the purpose of this article – to determine the role and place of computer science in training future teachers of mathematics.

2. Digitalisation as a basis for changes in natural and mathematics education

The meeting of the World Economic Forum in 2019 emphasized the changes in modern life and education in the era of the fourth industrial revolution (Industry 4.0). Manifestations of these changes was divided into physical, digital and biological by Klaus Schwab.

In particular, he includes to the physical innovations:

a) unmanned vehicles, which are controlled by user distantly or by software (based on machine learning methods);

b) 3D-printing, which provides the ability to materialize models created in computer-aided design systems;

c) advanced robotics, which is based on machine vision technologies, machine learning methods and other artificial intelligence technologies.

Klaus Schwab considers that such a representative of the digital block as the Internet of Things is “one of the main bridges between physical and digital reality” [15]. To build this bridge, workers of the near future must have the following leading skills: solving complex problems (projected demand – 36%), communication skills (19%), information processing skills (18%), system skills (17%), etc. Among other digital technologies in Industry 4.0, Schwab includes new computing technologies (mobile, cloud, and quantum computing), as well as blockchain and other distributed technologies. Among the technologies that change human existence, he identifies neurotechnology, augmented and virtual reality technology as the leading [16].

The development, implementation and effective use of Industry 4.0 technologies requires advanced key competences in mathematics, science, technology and engineering, and digital competence. This requires the transformation of education as a component of social transformation: from a society of steel and oil (III and IV technological stage) to the information society with computers, telecommunications and nanotechnology (V and VI technological stage). The main characteristic this society is a high level of information technology, developed infrastructures that provide the production of information resources and access to them, the processes of accelerated automation and robotisation of all branches of production and management, radical changes in socio-professional structures, resulting in the expansion of information activities.

The Recommendations of the 2016 Parliamentary Hearings on “Information and Communication Technologies Reforms and the Development of the Ukraine Information Space” [4] state that ICTs are becoming one of the most important factors of stimulating economic growth at the present stage of the global community’s transition to the information society. It is also stated that ICT help to bridge the “digital divide”. Regarding education and formation of ICT skills in the information society, it is recommended, in particular, to introduce compulsory study of programming principles in secondary schools within the subject “Informatics” and the subject “Programming” in senior classes of schools that specialise in physics and mathematics, information and communication technologies.

Among the especially relevant scientific, technical and socio-economic problems Myroslav I. Zhaldak refers to “problems of informatisation – the creation of a system of effective provision of timely, reliable and comprehensive information and data of all socially significant human activities, conditions for operational, thorough and comprehensive analysis of researched processes and phenomena, forecasting their development, predicting the consequences of decisions made. Their solution is inseparable from the solution of the problems of informatisation of the education system, which on the one hand reflects the achieved level of scientific, technical and socio-economic development of society and depends on it, and, on the other hand, significantly determines it” ([22], p. 8).

According to the Concept of Development of the Digital Economy and Society of Ukraine for 2018-

2020, the concept of digitalization was defined as the saturation of the physical world with electronic-digital devices, tools, systems and the establishment of electronic-communication exchange between them, which actually enables integrated interaction of virtual and physical, i.e., creates cyberphysical space [13].

The implementation of this Concept envisages radical changes in the field of education. Modern students need an interesting school filled with research and experiments using modern technologies. The use of digital technologies in school should be cross-platform in nature, i.e., to be used not only in Informatics lessons in a separate computer science class, as usual, but when teaching other subjects, when students interact with each other, with teachers, and with real experts, when students research and learn individually [6].

According to the Concept of development of digital economy and society of Ukraine for 2018-2020 [6] the main directions of digitalisation of education are:

- development and implementation of innovative computer, multimedia and computer-oriented learning tools and equipment for creating a digital learning environment (multimedia classes, research STEM-centers, laboratories, inclusive classes, blended learning classes);
- development of distance education using cognitive and multimedia technologies.

3. Relationships between mathematics and Informatics in the natural and mathematical field

Vladimir V. Laptev, Natalia I. Ryzhova and Mikhail V. Shvetckii [11] adhere to the definition of information technology as a set of systematic and mass methods of creating, accumulating, processing, storing, transmitting and distributing information (knowledge and data) by means of computer technology and communication, as well as the means of their integration and rational combination with non-machine information processing.

Zhaldak defines information technology as a set of methods, tools and techniques used for collection, storage organisation, processing, transferring and presentation of all kinds of messages and data [21].

The definition of new information technologies is also provided in the explanatory dictionary [1] as the technology for processing information and solving problems with use of computers, which is based on the achievements of artificial intelligence.

According to Andrey P. Ershov, applied informatics is a set of all types of human activity related to the use of software and hardware of the infosphere. The development of applied informatics finds its expression in the transfer to society of new information technologies of systematic or automated data processing in the interests of a particular human activity [9].

Laptev, Ryzhova and Shvetckii define informatics as a fundamental natural discipline, the object of which is the information processes that take place in the world. The basic concepts of informatics Laptev, Ryzhova and Shvetckii include information processes, structures of constructive mathematics (constructive objects and constructive processes), computer information models (data structures and algorithms), architecture of computing systems, and computational experiment [11].

We propose the definition of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, and the subject is new information technologies that are implemented using computer systems, and the methodology of informatics is a computational experiment.

Ershov notes the relationship of informatics to natural sciences: “Realizing some relativity of the division of science into natural and social, we assume informatics as natural science, according to the idea of the unity of the laws of information processing in artificial, biological and social systems” [8].

Laptev, Ryzhova and Shvetckii refer to informatics as a fundamental science, which reflects the general scientific nature of the concepts of “information” and information processes. As a fundamental science, informatics is associated with many other scientific fields, such as philosophy (in particular, epistemology and the doctrine of information), mathematics (in particular, algebra, mathematical logic and algorithm theory, the theory of mathematical modeling), linguistics (in particular, the doctrine of formal systems and formal languages), as well as information and management theory [11].

Mathematics is not only a parent science for informatics. This opinion is shared, in particular, by

Ershov, who believes that informatics itself in its formation necessarily uses mathematics in its basic principles and methods. That is why the methods of informatics penetrate into the depths of mathematics and affect some features of style, technique and content of mathematical education and activities: “the whole course of objective development of informatics shows that mathematics was not only the mother science for her, but also informatics itself are steadily mathematized in process of its formation and separation in its grounds and methods. Moreover, there is more and more evidence that the methods of informatics, certain information technologies penetrate into the depths of mathematics, affect some features of style, technique and content of mathematical work” ([9], p. 2).

Ershov demonstrated a parallel set of concepts of mathematics and informatics (table 1), which support the most important for informatics concept of performer (mathematical analogue – the concept of “algebraic system”), at the Sixth International Congress on Mathematical Education in the Plenary Report [9]. Ershov believed that the development of this connection is the mathematisation of the basics of informatics [8].

Table 1. Equivalence of concepts in mathematics and informatics.

<i>Mathematics</i>	<i>Informatics</i>
Algebraic system (Algebraic structure)	Executor (robot, computer, person in a certain role)
Set (Domain)	circumstance
Occurrence of a set	State of circumstance
Operation	Action that change the circumstance
Predicate	Questions to the circumstance
Signature	System of executive commands
Protocol (Sequence of operations and predicates with their values + initial element)	Activity (the sequence of actions and questions to the circumstance, starting from the initial state)
Predicate – precondition	Condition of the problem
Predicate – postcondition	Purpose of the problem
Valid protocol that implements the corresponding predicates of precondition and postcondition at the ends	Solving the problem (activity that leads from a state that satisfies the conditions to a state that satisfies the purpose)
Program (subcursive set, which includes a large number of valid protocols)	Program (finite instruction that defines the activity leading to the purpose for each state that satisfies the condition)

The relationship between computer science and mathematics was also pointed out by Aleksei L. Semenov. He emphasized that informatics has a theoretical core, which is closely related to mathematics, explaining that “the fundamental natural science part of informatics builds theoretical models of the processes of processing, accumulation and transmission of information. By its object, concepts and methods, it is a branch of mathematics. The subject of its study are the final (constructive) objects and algorithmically described (constructive) processes that occur in the environment of these objects” ([17], p. 54). Semenov calls this part of informatics “mathematical informatics” and notes that the foundation of mathematical computer science was laid in attempts to model the processes of human algorithmic activity.

In the development of mathematics as a science, Mikhael Gromov notes the role of informatics: “As the body of mathematics grew, it became itself subject to a logical and mathematical analysis. This has led to the creation of mathematical logic and then of the theoretical computer science. ... It absorbs ideas from the classical mathematics and benefits from the technological progress in the computer hardware which leads to a practical implementation of theoretically devised algorithms. ... And the logical computational ideas interact with other fields, such as the quantum computer project, DNA-based molecular design, pattern formation in biology, the dynamics of the brain, etc. One expects that in

several decades computer science will develop ideas on even deeper mathematical levels which will be followed by radical progress in the industrial application of computers, e.g., a (long overdue) breakthrough in artificial intelligence and robotics. ... As the power of computers approaches the theoretical limit and as we turn to more realistic (and thus more complicated) problems, we face the "curse of dimension" ... Here one needs a much higher level of mathematical sophistication in computer architecture as well as in computer programming ... Successes here may provide theoretical means for performing computations with high power growing arrays of data." [10].

4. Informatics in the modernization of training of future teachers of mathematics

There are higher education institutions of various types in Ukraine. Thus, the training of future teachers is conducted in multidisciplinary (classical) universities and branch (pedagogical). According to the Concept of development of pedagogical education [5], pedagogical education is a system of professional training of pedagogical workers to carry out pedagogical activity. At the same time, the professional qualification of a pedagogical worker is a standardized set of acquired competencies (dynamic combination of knowledge, skills and practical skills, ways of thinking, professional, ideological and civic qualities, moral and ethical values [20]) that is certified by the relevant document and allows to carry out professional pedagogical activities.

The training of future teachers must meet the public demands formulated in professional and educational standards, take into account global trends and recommendations of influential international organizations for teacher training. Teacher training programs contain components of psychological, pedagogical and practical training, including teaching methods and the use of information and communication and digital technologies. Modernization of educational programs should include, in particular, their focus on the formation of future teachers' research skills and mastery of information and communication technologies [5].

The importance of mathematics for the socio-economic and technological development of Ukraine is noted in the Law of Ukraine "On Higher Education", the list of acutely deficient specialties of which includes specialties of the fields of knowledge 01 – Education/Pedagogy, 11 – Mathematics and Statistics, 10 – Natural Sciences and Engineering. In particular, for entrants to natural-mathematical and engineering-technical specialties the corresponding privileges are provided.

The focus on improving the mathematical training of entrants is also reflected in the fact that, starting in 2021, external independent assessment in mathematics in Ukraine will be mandatory. As Liliia M. Hrynevych pointed out, "... from 2021 we plan to introduce a mandatory state final examination in mathematics in the form of external independent assessment. ... Mathematics plays a special role in the cognitive development of children, so its study is extremely important. Basic skills in mathematics are necessary for everyone – it develops logical and abstract thinking. And these are the skills that all people need. And more and more countries are making the external math exam compulsory for all children after school. ... We are now seriously preparing to strengthen from 2021 both the study of mathematics and English. These subjects are extremely important for a person, who wants to be competitive in today's world" [13].

The formation of mathematical competence of pupils requires a high level of professional competencies of mathematics teachers. The Concept of the State Targeted Social Program for Improving the Quality of School Natural and Mathematical Education for the Period up to 2015 emphasized that improving the quality of school mathematical education is a necessary condition for the formation of an innovative society and increasing the competitiveness of the economy. The Program was implemented together with the Action Plan to improve the quality of physical and mathematical education [12], which, in particular, provided for the need:

- to modernize the standards of higher education in the areas and specialties of physics and mathematics, including pedagogical profile;
- to bring the content of school physical and mathematical education in line with the modern development of science and social needs of society, to ensure the applied orientation of the content of curricula in mathematics and natural sciences;

- to improve the content of curricula in basic mathematical disciplines, taking into account the computerisation of all types of engineering activities (discrete and computer mathematics, fuzzy methods and “soft” calculations);

- to provide informatization of higher physical and mathematical education by including in physical and mathematical disciplines laboratory workshops with the system of computer mathematics, means of visualization of calculations;

- to ensure the teachers training for the formation of pupils' skills to interpretate quantitative information presented in tables, charts and graphs; to teach pupils to obtain the necessary information independently, analyze it, perform calculations and choose the best solution.

The realization of the tasks set in the Program and the Plan is impossible without thorough computer training of future mathematics teachers. The analysis of normative documents provides an opportunity to identify the following areas of modernisation of training of future teachers of mathematics:

- improving the system of professional information competencies of future mathematics teachers;
- introduction of computer mathematics systems in methodical systems of teaching mathematical disciplines with their subsequent transformation into computer-oriented ones;

- renewal of computer-oriented systems of teaching informatics of future mathematics teachers based on the widespread use of models and methods of mathematical computer science, in particular, through the integration of programming systems and computer mathematics in a cloud-based environment.

According to the Decree of the President of Ukraine “On declaring the 2020/2021 academic year as the Year of Mathematical Education in Ukraine”, the Cabinet of Ministers of Ukraine developed an appropriate action plan [7] to achieve given aims: ensuring equal access of pupils to mathematics; implementing modern technologies of mathematics; improving resource providing the educational process; increasing the motivation of pupils to study mathematics and its application in life; popularization of mathematics education. Among these actions the such:

- ensuring the introduction of training courses “Logic” and “Mathematical Logic” in the curricula of grades 1-11 of general secondary education;

- organization of summer “mathematical schools” for professional growth and formation of a professional community of teachers;

- development of methodical recommendations and practical tools for the use of interdisciplinary connections of mathematics with other educational disciplines;

- equipping general secondary education institutions with equipment for STEM laboratories.

According to Myroslav I. Zhaldak, such problems become important: 1) integration of educational disciplines, in particular mathematics, physics, informatics and others; 2) differentiation of training in accordance with the inclinations, requests and abilities of pupils. Informatics to some extent solves the problems of such integration, studying the general properties of information processes, laws and rules of search, creation, storage, analysis, systematization, processing, transmission, presentation and use of various messages and data. The integration of mathematics and informatics and other subjects cannot be reduced to their mechanical combining in the existing form. Existing modern computer-oriented methodological systems of training, on the contrary, are aimed primarily at the holistic perception of the studied phenomena, elucidation of their essence, the links between their individual manifestations, in particular: analysis of the semantic side of obtained formal solutions; development of synthetic, figurative thinking along with logical, analytical; abstraction from the technical details of the analysis of models of the studied phenomenon; problem statement; putting forward hypotheses, construction of information (including mathematical) models of researched processes and phenomena; material interpretation of the results obtained with help of computers ([22], p. 10).

Characterizing the impact of computerisation on mathematical education, Andrey P. Ershov outlines the following areas of influence [9]:

1. Sharp expansion of mathematical practice: “computerization is both a means and an expression of the expansion of mathematical knowledge”.

2. Changing the nomenclature of mathematical knowledge: “Abstractions of human activity, the

properties of artificial and living (biological and socio-technical) systems are included to substantive part of mathematics through programming and construction of information models. All this sharply enhances the role and place of discrete mathematics. This is facilitated by the shift in physics towards the quantum properties of matter”.

3. Systemic role of mathematical theory.

4. Computational experiment with a mathematical model: “its role in engineering practice is well known”; “its practicality as a new method of cognitive activity in the educational process is also confirmed by pedagogical practice”; “in recent years, the computational experiment has increasingly become a source of purely mathematical discoveries”.

5. Visualization of abstractions “... must be observed at the educational level between the abstract mathematical object and its visual model ... The importance of a bright visible image for the activation of the young mind is well known to every teacher, educator and psychologist”.

6. Dynamization of mathematical objects: “The computer with its means of visualization and computation help the observer to extract from the static packaging of mathematical relations all sorts of trajectories of the dynamic process in time and space, thus enriching his experience, intuition and ability to predict. All this brings the learning process closer to research and experiment”.

7. Formation of a structure out of chaos: “Among the possibilities provided by mathematical experimentation and the ability of the computer to visualize, special mention should be made of experiments to observe the formation of regular structures from the initial disorder. ... Here is formed a completely new and extremely powerful channel for the spread of mathematical knowledge to a huge class of natural phenomena: the movement of continents, the formation of the coastline, mountain landscapes, aurora borealis, plant formation, animal coloring, evolution of conflicts and genesis of crises. ... the material supplied by the synergetics and mathematics of the nonlinear give us possibility to draw an important educational conclusion about the fundamental importance of computational experiment as a cognitive tool: if the source of everything new in nature is nonlinearity, then speculative prediction of the extrapolation type is linear in nature and therefore it is limited in its cognitive power, for example, any conclusion in existing axiomatics. Therefore, the extraction of truly new knowledge requires a nonlinear synergistic process either in the human brain or in computer memory”.

8. Forming of basic abilities and skills: “... a computer with the possibility of direct manipulation with visual images of mathematical objects in artificial worlds can make ... the task of pre-mathematical ... education a subject component of the educational process, especially in primary education and in early adolescence. These are logical tasks and competitions in calculations in mind, drawing up and following the “rules of the game”, constructing artificial worlds, direct manipulation with mathematical objects, managing executors, planning their activities and much more”.

9. Awakening of primary interest: “... the dynamic, visual, obedient and stimulating style of computer behavior makes it an ideal tool for awakening the initial interest in mathematics, its beauty, surprise, prophetic power and magical connection with everything around”.

Vladimir M. Tikhomirov notes: “Mathematical education should include teaching computers, computer technology and modern information capabilities. These are the trends of the new time, and there is no doubt that the new century will be the age of Computers, as well as the centuries of Steam, Electricity, Atom. And it must be borne in mind that in mathematics itself there are events of paramount importance that must be included in mathematical education (catastrophe theory, fractals, discrete mathematics, etc.)” [18].

Considering the trend of mathematics development, attention is drawn to the close links between mathematics and informatics, which are manifested in the introduction of mathematical methods into informatical disciplines, and informatics methods penetrate into mathematics, influencing the content and means of mathematical activity. This is evidenced by the emergence of a new field – computer mathematics. The use of computers and information technologies make it possible to enrich mathematical science, expand its application, and significantly influence the mathematical activity itself (content, methods and means).

That is why high-quality training of a mathematics teacher is impossible without the formation of

key and professional informatics competencies. To do this, the student must have a range of knowledge and skills for the full use of ICT in the educational process.

5. Conclusion

The analysis of the current state of informatisation of society, the development of informatics and areas of reform of science and mathematics education provided an opportunity to draw the following conclusions:

1. Digitalising of education as a component of society requires a comprehensive integrated use of models, methods and means of informatics in teaching subjects of any field. At the same time, the prospects for the development of digitalising means should be reflected in the advanced content of teaching informatics disciplines at all levels of education. As a result of the analysis it is safe to say that the problem of training of future teachers in informatics needs special attention, because it is the teacher who must implement information and communication technologies directly into the educational process, form pupils' competencies in informatics, prepare a new generation for life in today's information society.

2. Mathematics and informatics are related sciences that significantly influence each other in the process of their development, and largely determine the development of natural sciences and technology. The definition of informatics as a complex scientific and engineering discipline, the object of which is information processes of any nature, and the subject is new information technologies that are implemented using computer systems, and the methodology of informatics is a computational experiment, provides an opportunity to consider it as a basis for integration natural sciences, ICT, engineering and mathematics in STEM education.

3. The main directions of modernisation of professional training of mathematics teachers are digitalising of research-oriented study of mathematics, informatisation of the learning content of mathematical disciplines and strengthening of training of mathematics teachers in informatics, in particular, programming of cyberphysical systems. Thus, it can be argued about the decisive role and place of computer science in the training of future mathematics teachers in Ukraine and around the world.

References

- [1] Averkin A N, Gaze-Rapoport M G and Pospelov D A 1992 *Explanatory Dictionary of Artificial Intelligence (Tolkovy slovar po iskusstvennomu intellektu)* (Moscow: Radio i svyaz) p 256
- [2] Cabinet of Ministers of Ukraine 1993 About the State National Program "Education" ("Ukraine of the XXI Century") (Pro Derzhavnu natsionalnu prohramu "Osvita" ("Ukraina XXI stolittia")) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/896-93-%D0%BF>
- [3] Cabinet of Ministers of Ukraine 2013 On approval of the Information Society Development Strategy in Ukraine (Pro skhvalennia Stratehii rozvytku informatsiinoho suspilstva v Ukraini) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/386-2013-%D1%80>.
- [4] Cabinet of Ministers of Ukraine 2013 On the recommendations of the parliamentary hearings on the topic: "Reforms of the information and communication technologies and the development of the information space of Ukraine" (Pro rekomendatsii parlamentskykh slukhan na temu: "Reformy haluzi informatsiino-komunikatsiinykh tekhnolohii ta rozvytok informatsiinoho prostoru Ukrainy") *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/1073-19>
- [5] Cabinet of Ministers of Ukraine 2018 *About the statement of the concept of development of pedagogical education (Pro zatverdzhennia kontseptsii rozvytku pedahohichnoi osvity)* URL <https://mon.gov.ua/ua/npa/pro-zatverdzhennya-koncepciyi-rozvytku-pedagogichnoyi-osviti>
- [6] Cabinet of Ministers of Ukraine 2018 *The concept of development of the digital economy and society of Ukraine for 2018-2020 (Kontseptsia rozvytku tsyfrovoy ekonomiky ta suspilstva Ukrainy na 2018-2020 roky)* URL

- <https://www.kmu.gov.ua/storage/app/uploads/public/5a7/c21/c86/5a7c21c867bde621479479.doc>
- [7] Cabinet of Ministers of Ukraine 2020 On approval of the action plan for the Year of Mathematical Education in Ukraine in the 2020/21 academic year (Pro zatverdzhennia planu zakhodiv shchodo provedennia Roku matematychnoi osvity v Ukraini u 2020/21 navchalnomu rotsi) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/630-2020-%D1%80#Text>
- [8] Ershov A P 1986 Informatika: predmet i poniatiia (Informatics: subject and concepts) *Kibernetika. Stanovlenie informatiki (Cybernetics. Formation of informatics)* (Moscow: Nauka) pp 28–31
- [9] Ershov A P 1988 *Kompiuterizatciia shkoly i matematicheskoe obrazovanie (Plenarnyi doklad 6-mu Mezhdunarodnomu kongressu po matematicheskomu obrazovaniiu) (School computerization and mathematics education (Plenary talk to the 6th International Congress on Mathematical Education))* URL <http://ershov.iis.nsk.su/ru/node/768505>.
- [10] Gromov M 1998 Possible Trends in Mathematics in the Coming Decades *Notices of the AMS* **45**(7) 846–847
- [11] Laptev V V, Ryzhova N I and Shvetskii M V 2003 *Metodologicheskaia teoriia obuchenii informatike. Aspekty fundamentalnoi podgotovki (Methodological theory of teaching computer science. Aspects of fundamental training)* (Sankt-Peterburg: Izdatelstvo Sankt-Peterburgskogo universiteta)
- [12] Ministry of Education and Science of Ukraine 2008 On approval of the Action Plan to improve the quality of physical and mathematical education for 2009-2012 (Pro zatverdzhennia Planu dii shchodo polipshennia yakosti fizyko-matematychnoi osvity na 2009-2012 roky) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/rada/show/v1226290-08>
- [13] Ministry of Education and Science of Ukraine 2019 *From 2021, the EIT in mathematics will have 2 levels and will be mandatory (Z 2021 roku ZNO z matematyky matyme 2 rivni ta bude oboviazkovym dlia skladannia)* URL <https://mon.gov.ua/ua/news/z-2021-roku-zno-z-matematiki-matime-2-rivni-ta-bude-obovyazkovim-dlya-skladannia>
- [14] President of Ukraine 2020 About the announcement of the 2020/2021 academic year as the Year of Mathematical Education in Ukraine (Pro oholoshennia 2020/2021 navchalnoho roku Rokom matematychnoi osvity v Ukraini) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/31/2020#Text>
- [15] Schwab K 2016 The fourth industrial revolution (Cologne: World Economic Forum) p 189
- [16] Schwab K and Davis N 2018 Shaping the Fourth Industrial Revolution (Cologne: World Economic Forum) p 289
- [17] Semenov A L 1995 Mathematical computer science at school (Matematicheskaiia informatika v shkole) *Informatika i obrazovanie* **5** 54–8
- [18] Tikhomirov V M 2000 On some problems of mathematical education (O nekotorykh problemakh matematicheskogo obrazovaniia) *Vserossiiskaia konferentciia "Matematika i obshchestvo. Matematicheskoe obrazovanie na rubezhe vekov"* (Dubna, Ratmino) URL <https://www.mccme.ru/conf2000/tikh.htm>
- [19] Verkhovna Rada of Ukraine 2007 On the Basic Principles of Information Society Development in Ukraine for 2007-2015 (Pro Osnovni zasady rozvytku informatsiinoho suspilstva v Ukraini na 2007-2015 roky) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/537-16>
- [20] Verkhovna Rada of Ukraine 2014 About higher education (Pro vyshchu osvitu) *Legislation of Ukraine* URL <https://zakon.rada.gov.ua/laws/show/1556-18>
- [21] Zhaldak M I 2003 Pedagogichnyi potentsial kompiuterno-oriietovanykh system navchannia matematyky (Pedagogical potential of computer-oriented mathematics teaching systems) *Kompiuterno-oriietovani systemy navchannia* **7** 3–16
- [22] Zhaldak M I 2013 Problemy informatyzatsii navchalnoho protsesu v serednikh i vyshchykh navchalnykh zakladakh (Problems of informatization of the educational process in secondary and higher educational institutions) *Kompiuter u shkoli ta simi* **3** 8–15