# Methodical System of Teaching Informatics to Pre-Service Mathematics Teachers

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Abstract: The article is devoted to the problem of development and implementation of computer-oriented methodical system of teaching informatics to pre-service mathematics teachers. Based on the analysis of scientific literature, the role and place of informatics in the competence-oriented training of pre-service mathematics teachers are revealed; the structure, content, indicators and levels of informatics competencies formation of pre-service mathematics teachers are clarified and characterized; the model of computer-oriented methodical system of teaching informatics to pre-service mathematics teachers has been developed. Theoretically grounded and developed the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, consisting of the target (formation of informatics competencies of pre-service mathematics teachers), design (design the system of informatics competencies and methodical system of teaching), technological (creation of a computer-oriented learning environment for informatics courses) and result blocks; its experimental verification was carried out and confirmed on the basis of the developed criteria and indicators.

## 1 INTRODUCTION

The Law of Ukraine "About the Basic principles of development of information society in Ukraine for 2007-2015" defines the creation of an education system focused on the use of the latest digital technologies in the formation of a comprehensively developed personality as the main strategic goal of the development of the information society in Ukraine (Verkhovna Rada of Ukraine, 2007). To achieve this goal, the "Strategy for the Development of the Information Society in Ukraine" (Cabinet of Ministers of Ukraine, 2013) defines a number of priority areas of state policy, the implementation of which will ensure the improvement of the educational process, accessibility and effectiveness of education. Leading among them are: formation and development of the informational educational environment in the system of general secondary and higher education; implementation of an information system for supporting the educational process; development of the distance learning system and ensuring, based on it, the effective implementation and use of digital technologies at all educational levels of all forms of education (Cabinet of Ministers of Ukraine, 2013).

According to the "Concept of the Development of the Digital Economy and Society of Ukraine for 2018-2020", the main directions of digitalization of education are the development and implementation of innovative computer-oriented learning tools to create a digital learning environment and the development of a distance form of education using cognitive and multimedia technologies (Cabinet of Ministers of Ukraine, 2018). The main driver of the digitization of education is a competent teacher, whose training must meet social demands, take into account world trends and recommendations of influential international organizations. Among the factors of the imbalance between the public demand for highly qualified pedagogical workers, the prospects for the development of society, global technological changes and the existing system of pedagogical education, as well as the level of readiness / ability of modern teachers to implement educational reforms in Ukraine, the leading ones are the outdated content, structure, standards and methods of teaching in system of pedagogical education, as well as the inconsistency of key professional competencies of graduates of pedagogical education insti-

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tutions with the challenges of the digital society.

The action plan for improving the quality of physical and mathematical education involves: bringing the content of physical and mathematical education in line with the modern development of science and the needs of society; digitization of mathematics education by including laboratory workshops with a computer mathematics system, calculation visualization tools in mathematical disciplines; training of teachers to develop in students the ability to interpret quantitative data presented in tables, charts and graphs, teaching students to independently obtain the necessary information, analyze it, perform calculations and choose the optimal solution (Ministry of Education and Science of Ukraine, 2008). The decree of the President of Ukraine "On the declaration of the 2020/2021 academic year as the Year of Mathematics Education in Ukraine" provides for the creation of conditions for equal access to modern and high-quality mathematics education and ensuring the modern level of teaching mathematics disciplines, in particular with the use of effective technologies taking into account the best domestic and international practices (President of Ukraine, 2020).

Therefore, there is a socially determined and legally justified need to improve the quality of training of future teachers of mathematics, in particular informatics training. One of the leading directions for achieving this goal is the development and implementation of computer-oriented methodical systems and training tools for future teachers of mathematics.

## 2 THEORETICAL BACKGROUND

The problems of development, modification and implementation of computer-oriented methodological systems for teaching mathematics and informatics in institutions of general secondary and higher education were studied by Bieliavtseva and Kanevska (Bieliavtseva and Kanevska, 2007), Vlasenko et al. (Vlasenko et al., 2020), Horoshko and Pokryshen (Horoshko and Pokryshen, 2010), Gubanov (Gubanov, 2010), Zhaldak et al. (Zhaldak et al., 2021), Klochko (Klochko, 2017), Tryus (Tryus, 2010), Shokaliuk (Shokaliuk, 2012) and others.

The professional competences of the future mathematics teacher are considered in (Zhukova, 2009; Ramskyi, 2013; Marienko, 2022; Lovianova et al., 2019; Semenikhina et al., 2022; Rakuta, 2013; Matiash and Mykhailenko, 2020; Skvortsova and Romanyshyn, 2019; Hrabovskyi, 2016; Lebedyk, 2017; Razlivinskih, 2011; Sadulaeva, 2012). In particular, the use of digital technologies in the training of future mathematics teachers and the formation of their IT competences is highlighted in (Bilousova and Zhytienova, 2010; Gubanov, 2010; Zhaldak, 2003; Zhernovnykova et al., 2020; Kirilenko, 2009; Kolgatin et al., 2022; Krishtof, 2011; Robert et al., 2016; Kushnir, 2014; Sarkeeva, 2010; Senkevich, 2005).

Analysis of the current state of development of the information society in Ukraine and the world (Schwab, 2016; Schwab and Malleret, 2020), the potential of information technologies as a means of integrating mathematics, computer science and natural sciences (Gromov, 2001; Semenov, 1995; Karakozov and Ryzhova, 2019), as well as the problems of informatics training of future mathematics teachers (Ershov, 1987; Zhaldak et al., 2012; Tikhomirov, 2000) discovered that the prospects for the development of digitization tools should be reflected in the anticipatory content of teaching informatics disciplines at all levels of education. Therefore, modernization of IT training and IT competences of future teachers needs special attention (Zhukova, 2009; Ramskyi, 2013), since it is the teacher who must introduce digital technologies into the educational process, form students' IT competences, and prepare the new generation for full-fledged life in the information society.

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 technologies. The main source for changes in the education system is the public order, which reflects the development of technology, science and socio-economic relations. In the 20s of the 21st century, this complex, named Industry 4.0, is extremely computerized, which makes it necessary to clarify the IT competencies of future teachers by reflecting new content and new abilities. It is shown that the formation of key and subject information-communication (digital) and mathematical competences in the European educational space is considered as a component of the fundamental literacy of workers in demand on the labor market of the future. Therefore, in the process of forming general professional digital competences of the teacher, it is necessary to take into account such basic ICT innovations as open educational resources, social networks, mobile technologies, the Internet of Things, artificial intelligence, virtual and augmented reality, big data, programming, ethics and privacy protection.

As a result of the analysis of domestic, foreign (Commonwealth of Australia, 2022; Association of Mathematics Teacher Educators, 2017) and international (UNESCO, 2018) teacher training standards, the components and indicators of such general professional digital competences as the ability to: eval-

uate, implement and use ICT-oriented educational platforms have been determined; application of e-learning in social media; pedagogical design for e-learning; analysis, implementation and evaluation of the effectiveness of evaluation; application of ICT-related knowledge; implementation of improved educational practices; analysis of industrial implementations and e-learning systems. Special attention should be paid to the recommendations of the Association of Mathematics Teacher Educators and the National Council of Teachers of Mathematics of the USA aimed at pedagogically appropriate and balanced use of ICT in teaching mathematics in general secondary education institutions.

The generalization of the theoretical provisions gave reason to specify the structure, indicators and levels of formation of the IT competencies of the future mathematics teacher: at the first (initial) level, competencies related to performing tasks with the help of a personal computer, various software and digital devices are formed; at the second (minimum basic) competences in the use of ICT in any field are formed; the third (basic) develops competences in a wide range of ICT, including animation, the basics of cloud technologies, cyber security, digital media, computer networks, programming, computer systems and web development; the fourth (advanced) develops digital competencies related to solving a wide range of problems related to database management, computer game development, computer network configuration, programming, system administration, and web development; the fifth (in-depth) level provides for further development of general professional and formation of specialized competencies in computer networks, programming, web development, business analysis, cloud computing, cyber security, databases, design and development of computer games, system administration and system analysis; the sixth (research) level completes the process of forming informatics competencies of future mathematics teachers at the second level of higher education.

## 3 EMPIRICAL RESEARCH OF STUDENTS' VIEWPOINTS

Based on the analysis of various approaches to the design and development of methodical systems of education, the components of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers are determined. The choice of a methodical system as an object of modeling is related to the need to reflect in the model its structural components, technologized in terms of competencies, results and goals, external factors affecting the system, principles and approaches to its design. In the developed model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (figure 1), ICTs determine the goal, serve as design factors and leading means of teaching informatics disciplines.

The model consists of four blocks.

The target block reflects the goal: the formation of informatic competences of future teachers of mathematics, which is a component of the professional competences of a mathematics teacher, which are summarized in integral competence: the ability to solve complex specialized tasks and practical problems in the field of general secondary education in the process of teaching mathematics, which involves the application of psychological-pedagogical theories and teaching methods and is characterized by complexity and uncertainty of conditions. The formulation of the goal involved taking into account social, educational and information technology factors: crisis phenomena in science and mathematics education, the social need for competent mathematics teachers, the need to change professional IT competencies and new means of Industry 4.0.

The design block reflects the process of designing the system of informatics competences of the mathematics teacher and the core of the methodological system of learning, which consists of interconnected components (goals, content and technology of learning informatics) based on systemic, competence-based, activity-oriented and personally-oriented methodological approaches and the principles of a harmonious combination of traditional and innovative technologies, continuity, extensibility, invariance and variability, predictability, contextuality, integrability; general didactic and partially didactic principles of teaching informatics and principles of designing an open methodical system: feedback, dynamic balance, integrity and structural stability of the system.

The system of IT competencies of a mathematics teacher is designed in the form of a hierarchy, each level of which is a certain specialization or specification of the previous one: at the first level there are basic IT competencies, which at the second level are specified in competencies in system administration, web technologies, programming and system analysis; the third level reflects the development of: competencies in system administration – in competencies in computer networks and cyber security, competencies in web technologies – in competencies in cloud technologies, competencies in programming – in competencies in the development of computer games, com-

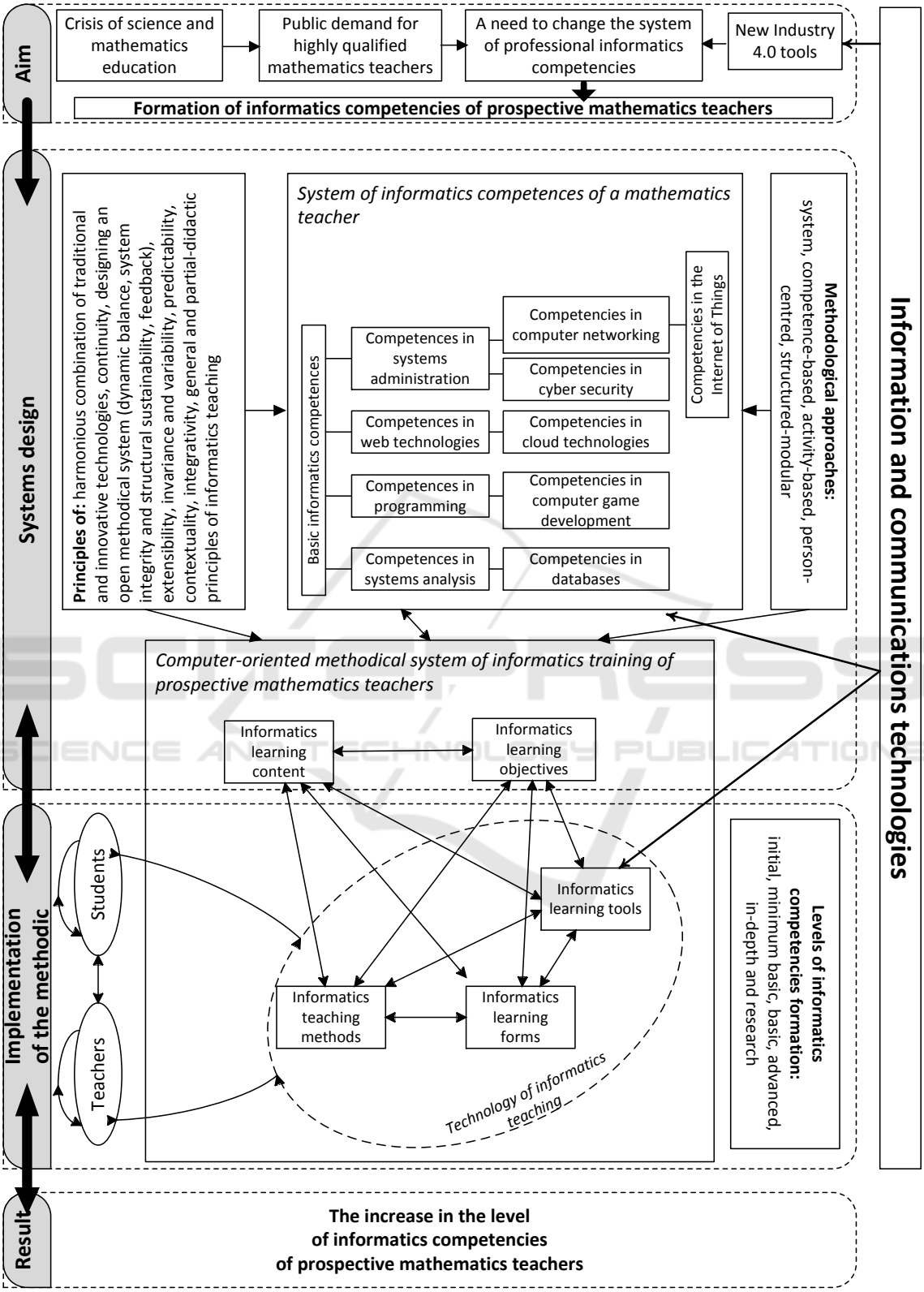


Figure 1: Model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (Semerikov et al., 2021).

petencies in system analysis – in competencies in databases; the fourth level reflects promising competencies in the Internet of Things, which is the development of competencies in computer networks.

The components of the system are interconnected not only through the learning goals and the technological result, formulated in terms of the informatics competencies of the mathematics teacher, but also through the content of education by mapping: the structure of informatics competencies – to the structure of informatics training in the relevant educational program; the content of informatics competences - on the content of training in informatics disciplines; mandatory and optional IT competences – for the structuring of IT disciplines.

The technological block reflects the process of creating a computer-oriented learning environment for informatics disciplines, in which there is direct and ICT-mediated educational communication between teachers and students, monitoring and diagnosis of the level of formation of informatics competencies at one of six levels: initial, minimum-basic, basic, advanced, in-depth and research.

The resulting block of the model reflects the projected goal of applying the developed methodical system: increasing the level of formation of informatics competencies of future mathematics teachers. The latter is considered both as a current result, which is diagnosed in the process of forming informational competences, and as a component of the overall result of professional training, which is diagnosed after the completion of the process of their formation.

Semerikov et al. (Semerikov et al., 2021) defines the principles of classification of teaching aids, selects teaching aids for general and special purpose IT disciplines, and provides elements of their application methodology. The interrelationships of the informatics competencies of future mathematics teachers with a wide range of tools have been revealed, which made it possible to characterize the following groups of leading tools for teaching informatics disciplines: communication tools; means of creating documents; means of access to databases; means of digital media technologies; hardware testing tools; software development and testing tools; project management tools; computer modeling tools.

In the training of informatics disciplines of future teachers of mathematics, it is appropriate to use learning strategies (Ploetzner, 2012) – sequences of effective teaching methods used purposefully and flexibly are increasingly automated, but remain consciously applied: yes, the method of problem presentation, heuristic and research the methods can be used both sequentially with increasing the level of formation of students' IT competences, and simultaneously in a group of students with different levels of their formation.

# 4 COURSEWARE STRUCTURE AND BACKGROUND OF EMPIRICAL STUDY

Experimental work on the research problem took place in 3 stages:

1) the *analytical-declarative stage* (2012 – 2013), the task of which was to study the state of computer science education of future mathematics teachers and to determine approaches to solving the research problem. In order to implement the set tasks, dissertations, domestic and foreign standards for the training of mathematics teachers, sources on computer science education and the formation of digital competencies of the future mathematics teacher were analyzed, which made it possible to formulate a research hypothesis. At the first stage, the main attention was paid to the issues of using ICT means of organization, monitoring and diagnosing the results of independent work of students in informatics disciplines. The conditions for the use of distance learning technologies in the training of future mathematics teachers were determined, and the content and forms of organization of training in informatics disciplines were selected. The identified problems of informatics training of future mathematics teachers provided an opportunity to identify competence and system approaches as leading to achieving the research goal;
2) the *design and research stage* (2014 – 2016) is dedicated to clarifying the structure and content of the mathematics teacher's informatics competencies and justifying the feasibility of using Web 2.0 tools for the development of research telecommunications projects, mathematical packages as universal programming and modeling environments, cloud-oriented the G Suite tool for comprehensive online support for teaching informatics disciplines for future mathematics teachers. At the second stage, the main components of the model of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers were determined and the ascertaining stage of the pedagogical experiment was conducted;
3) the formative and generalizing stage (2017 – 2020) is devoted to the development and implementation of a computer-oriented methodical sys-

tem for training informatics disciplines for future mathematics teachers. The formative stage of the pedagogical experiment was conducted; the obtained results of experimental work were analyzed, elaborated and summarized; general conclusions are formulated and prospects for further research are determined.

114 students of Kharkiv National Pedagogical University named after H. S. Skovoroda and Kryvyi Rih State Pedagogical University took part in the formative stage of the pedagogical experiment to test the effectiveness of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers (the control group 71, experimental – 43). Comparison of the distributions of participants of the control and experimental groups at the beginning of the experiment using the H-criterion of Kruskal-Wallis showed the absence of statistically significant differences between them at the 0.05 level ($H = 3.6435 < H_{crit}(0.05) = 5.991$).

The training of informatics subjects of the students of the experimental group was carried out according to the updated educational programs. In particular: in the educational discipline "Informatics", aimed at the formation of basic IT competencies of a mathematics teacher, the content module "Hardware and software of computing systems" has been updated to ensure the formation of basic competencies in the basics of system administration and application software for automating the document flow of an educational institution and competences for organizing safe joint work in a cloud-oriented educational environment; content modules have been introduced to the educational discipline "Methodology of Informatics Education" to ensure the formation of basic competencies in intellectual property, development and implementation of educational innovations, interaction with educational ICT clients and project activities; in the educational discipline "Computer Networks", content modules related to the design, installation, configuration and management of local networks of the scale of a computer class, support of network ICT systems, troubleshooting of computer networks have been updated, network security, Internet of Things, installation and configuration of virtual machines and desktop virtualization; the content modules of the educational discipline "Programming Languages" reflect competence in programming technologies, object-oriented programming, database programming, designing user interfaces, developing mobile applications and software extensions.

To ensure the formation of competences in web and cloud technologies and the development of computer games, new educational disciplines "Cloud technologies" and "Development of computer games" were introduced, which consider the issues of developing websites, social media, choosing and configuration of cloud services, 2D and 3D modeling, complex design and development of 3D interactive games (including mobile and online), their content and media components, characters with elements of artificial intelligence, as well as the creation of game environments for the organization of joint educational activities.

The effectiveness of the methodical system was determined by measuring the level of formation of IT competencies at 6 levels: initial (0-51 points), minimum-basic (52-60 points), basic (61-70 points), advanced (71-80 points), in-depth (81-90 points) and research (91-100 points). After the completion of the formative stage of the pedagogical experiment, the comparison of the distributions of students of the control and experimental groups according to the level of formation of IT competences using the $\chi^2$ Pearson test showed that they have statistically significant differences at the 0.01 level $\chi^2 = 17.253 > \chi^2_{crit}(0.01) = 15.086$. Taking into account the presence of individual violations of the conditions for applying the Pearson's $\chi^2$ test (in 25% of the categories, the number of observations was less than 5), an additional test of the hypothesis that the level of formation of IT competences in the experimental group increased was performed using Fisher's angular transformation: $\phi^* = 3.969 > \phi^*_{crit}(0.01) = 2.31$, which is the basis for the conclusion that in the experimental group the level of formation of IT competencies has increased, and therefore, the research hypothesis is proven.

## 5 RESULTS AND DISCUSSION

In order to test the effectiveness of the developed computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, a formative stage of the pedagogical experiment was conducted, during which 71 students studied according to the traditional methodical system (control group), and 43 students – according to the author's method (experimental group). Using the Kruskal-Wallis test, it was established that at the beginning of the experiment, the distributions of participants in the control and experimental groups did not have statistically significant differences. After the experiment was completed, the level of formation of the informatics competencies of mathematics teachers was diagnosed, and statistically significant differences at the 0.01 level were established in the distributions of students of the control and experimental groups

according to the Pearson criterion ($\chi^2 = 17.253 > \chi^2_{crit}(0.01) = 15.086$), and by applying the angular Fisher's transformation confirmed the statistical significance of the increase in the level of formation of IT competencies of the students of the experimental group ($\phi^* = 3.969 > \phi^*_{crit}(0.01) = 2.31$). Taking into account that the experimental group used the developed computer-oriented methodical system of teaching informatics to pre-service mathematics teachers, the indicator of the effectiveness of which is the diagnosed increase in the level of formation of informatics competences, it was concluded that the research hypothesis is proven.

# 6 CONCLUSIONS

The conducted analysis of the current state of informatization of society, the development of information technologies and the directions of reforming STEM education made it possible to conclude that its digitalization requires an end-to-end comprehensive appropriate use of models, methods and tools of informatics, systematic design of the anticipatory content of learning in informatics disciplines and modernization of informatics training of future teachers of mathematics.

It is shown that informatics as a complex discipline, the object of which is information processes of any nature, the subject is new information technologies, and the methodology is a computational experiment, is the basis for the integration of natural sciences, ICT, engineering and mathematics in STEM education.

The main areas of modernization of the professional training of mathematics teachers are identified and characterized: digitalization of research-oriented teaching of mathematics, informatization of the content of the teaching of mathematical disciplines, and strengthening of the IT training of mathematics teachers. It is substantiated that future teachers of mathematics should master new information technologies (mobile, ubiquitous, cloud-fog and quantum computing) and the ability to remotely manage social (in the process of distance learning) and cyber-physical systems, as well as the application of mathematical methods and models of artificial intelligence to them intelligence for the implementation of optimal management of training and robotic systems.

According to the results of the analysis of the standards of key competences, basic and full secondary education, training of teachers and specialists in information technology, the system of computer competences of the mathematics teacher was clarified in terms of structure, content and indicators of their formation. It is shown that the formation of IT competences of a mathematics teacher begins with basic IT competences: from the basics of system administration, in application software, from the organization of safe joint work, from digital media, from intellectual property, from the development and implementation of innovations, from interaction with educational ICT clients and project activities. Further development of basic IT competences takes place: in competences in system administration, which acquire further development in competences in computer networks (in computer network administration, in troubleshooting computer networks, in network security and in virtualization) and the Internet of Things, as well as competences in cyber security; in competences in web technologies, which acquire further development in competences in cloud technologies; in programming competences, which acquire further development in computer game development competences; competencies in system analysis and competencies in databases.

A model of a computer-oriented methodical system for training informatics disciplines for future mathematics teachers has been developed, which consists of four blocks: 1) target, which defines the goal of forming the informatics competencies of future mathematics teachers; 2) design, which reflects the process of designing the system of informatics competences of the mathematics teacher and the components of the methodical system of learning (goals, content and technology of learning informatics), interconnected on the basis of systemic, competence-based, activity-oriented and personally oriented methodological approaches and the principles of a harmonious combination of traditional and innovative technologies, continuity, extensibility, invariance and variability, predictability, contextuality, integrability, general didactic and partially didactic principles of teaching computer science and principles of designing an open methodical system; 3) technological, which reflects the process of creating a computer-oriented learning environment for informatics disciplines, in which direct and ICT-mediated educational communication, monitoring and diagnosis of the level of formation of informatics competencies takes place; 4) result, which reflects the achievement of the predicted result of the application of the model – increasing the level of formation of informatics competencies of future mathematics teachers.

The developed model is specified in the components of the computer-oriented methodical system of teaching informatics to pre-service mathematics teachers. Competencies related to innovative

means of general education (electronic educational resources, social networks, mobile technologies, programming tools, virtual and augmented reality tools) and special purpose tools (means of compliance with confidentiality and ethics of data processing, Internet tools) are reflected in the content of training in informatics disciplines. things and means of artificial intelligence). It was determined that the leading means of teaching informatics disciplines for future teachers of mathematics are means of communication; creation of documents; access to databases; digital media technologies; hardware testing; development and testing software development; project management; computer modeling. It is shown that the educational activity of future teachers of mathematics acquires a research orientation under the condition of constructing educational strategies from methods of active learning, in particular, the method of projects, trainings, business games, cooperative learning. The selected learning strategies determined the choice of forms of organization of the educational process in general, educational classes in informatics, educational activities in class, independent work, practical training and forms of organization of control activities.

## 7 PROSPECT FOR FUTURE RESEARCH

The performed research does not cover all aspects of the analyzed problem. Further scientific searches for its solution are expedient in the following directions: integration of programming systems and computer mathematics in the professional training of future mathematics teachers; modernization of learning calculation methods based on the use of models and artificial intelligence tools; integrated teaching of mathematics and informatics in a specialized school; application of means of an immersive environment for the development of virtual manipulatives.

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