Informational mathematical competence as a predictor of critical thinking of students of pedagogical directions

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Abstract. The aim of the research is to modernize the structure and content of the information and mathematical competence (IMC), as well as design a model of its development among students of pedagogical directions. By the method of theoretical analysis, the concept of information and mathematical competence was clarified, its characteristic features and structural components were determined. It is proposed to design a model for the development of an IMC based on the principles of compliance with the key competencies of the future, the requirements of the federal state educational standard and the corresponding professional standards. Thus, this model includes target, meaningful, technological and effective components. The target component actualizes the IMC development as a readiness to apply mathematical knowledge, skills and abilities, as well as ICT tools for searching, critical analysis and synthesis of information, solving complex problems in professional and subject areas. The content component reflects the invariant and variable components of the curriculum, which are revealed in the disciplines of the compulsory part and the part formed by the participants in educational relations. The technological component reveals methods and technologies, as well as forms and means of teaching. The effective component is presented in three aspects: motivational-value, emotional-strong-willed, reflexive. By the means of a pedagogical experiment, the effectiveness of the designed model in the point-rating system was assessed and a hypothesis was put forward about the predictive role of the IMC in the development of critical thinking of students.

1. Introduction
The new requirements of the Federal State Educational Standards of Higher Education are related to a competence-based approach to learning outcomes and goals, and within the nine categories of universal competencies common to all areas of education, the category “system and critical thinking” occupies the first position. In this regard, it is of particular importance to train specialists who possess universal competencies in the field of system and critical thinking, are able to effectively realize their creative and scientific potential, are mobile, and are ready to solve professional problems at a high level of success.

Special requirements apply to the preparation of bachelors in pedagogical areas. A modern teacher should possess ICT competencies, as well as “soft skills” competencies: have a high level of emotional intelligence, be able to work in a team, effectively build communication, show leadership qualities and make operational decisions.

Mathematics, as a tool for systematic knowledge of the world and critical analysis of objective reality, plays a particularly important role in education, and information and mathematical competence
(IMC) can be considered as a predictor of critical thinking of a future teacher. From this point of view, the study of the processes of formation and development of information and mathematical competence of students in pedagogical areas, as well as the mechanisms for managing these processes in the electronic information and educational environment (EIEE) is very promising.

Currently, critical thinking is one of the leading competencies of the future. For the first time, the concept of critical thinking as a special ability of a person was introduced by psychologist D. Halpern, who defines the ability to critical thinking as a method of cognition that is characterized by validity, controllability and purposefulness [1]. Experts identify the following features of critical thinking: properly organized memory (storing and reproducing information); language skills as a tool for thinking; the ability to extract meaning from information; ability to make logically correct judgments; ability to analyze and evaluate arguments; ability to formulate and test hypotheses; ability to make judgments about uncertainty and probability; discipline in decision-making; ability to solve clearly and vaguely set tasks.

Analysis of behavioral indicators of critical thinking presented in the research of domestic and foreign authors [2-4], it allows us to consider information and mathematical competence as a predictor of such thinking.

The problem of forming mathematical competence in the system of basic and secondary General education was studied in the works of S. L. Atanasyan, A. L. Semenova, [5] and others. Defining the mathematical competence of students, such characteristics are distinguished as the possession of a characteristic style of thinking (abstractness, evidence, rigor); the ability to argue and scientific communication; the ability to apply model means of mathematics to solve problems that arise in the world around them; the ability to independently carry out activities (algorithmic and heuristic); ability to create a personal information resource. In the international study of educational achievements of PISA students, mathematical competence is considered as a manifestation of mathematical literacy, the ability to identify a practical problem solved by means of mathematics, the ability to formulate and solve the corresponding mathematical problem, and interpret the result in the language of the problem [6].

The problem of forming mathematical competence of students in the higher education system is considered in the works of L. V. Shkerina [7], N. A. Kazachek [8], M. Yu. Glotova [9] and others.

In separate studies, issues related to the development of mathematical competence in integration with other competencies of University students of different directions and training profiles are considered. Thus, in the work of N. S. Yushchenko, N. I. Nikitina, G. S. Zhukova [10] information and mathematical competence is defined as an integrative personal and professional education of a specialist, reflecting the unity of his theoretical and fundamental training and practical ability to effectively apply mathematical methods and computer technologies to solve professional problems. Velikhanova introduces the concept of information and mathematical competence, presenting it as a multi-level structure [11]. In the work of D. N. Shekhovtsova, this concept is considered as an integral part of information and mathematical culture and is revealed through its definition [12].

In our opinion, global changes in society related to Informatization and digitalization, changes in professional standards, education standards and key competencies of the future require adjustments to the structure, content, and model of development of information and mathematical competence of the future teacher.

The purpose of this article is to present a model for the development of information and mathematical competence of students of pedagogical directions and to evaluate its effectiveness by means of statistical analysis.

2. Materials and methods
In the course of research, we used the methods of theoretical research: analysis of scientific literature, University programs, textbooks and manuals on mathematical disciplines, analysis of the organization of the process of experimental teaching of academic disciplines for students of pedagogical directions; methods of empirical research: observation, testing, conducting pedagogical measurements, experimental teaching of mathematical disciplines.
By the method of theoretical analysis, the characteristic features of information and mathematical competence are determined and a structural and content model of its development is designed for students of pedagogical directions on the basis of an integrative approach in the conditions of EI EE functioning.

During the pedagogical experiment, students were trained using e-courses developed on the basis of the Learning Management System Moodle platform, using e-learning tools and services. This made it possible to use mixed learning technologies in the educational process: Pre-Vodcasting, Flipped Class. In the future, the training process is aimed at developing academic virtual mobility of students (online training using MOOCs (mass open online courses) on foreign and domestic online platforms). To organize independent work and conduct practical classes, we used specially developed integrative textbooks that update inter-subject connections (mathematical methods for processing research results - computer science; system analysis and fundamentals of mathematical information processing – computer science, as well as disciplines defined by the profile of the direction: biology, geography, literature, foreign language, etc.).

During the experimental training, students were offered research tasks and tasks, contextual tasks, integrated tasks, and case tasks. The study involved undergraduate students of the 1st and 2nd year of pedagogical directions. Thus, about 350 people took part in the experiment.

To process the results of the study, statistical analysis methods were used as a guarantee of the objectivity of the result.

3. Results
Determining the structural and content model of information and mathematical competence of the future teacher, we were guided by the following principles:

- Compliance with the key competencies of the future. Soft skills are mental and interpersonal competencies: social, intellectual and strong-willed: sociability, ability to work in a team, creativity, punctuality, balance. According to the forecasts of analysts of the World Economic Forum, one of the most popular competencies will be: the ability to solve complex problems; critical thinking; creativity; coordination and interaction skills; emotional intelligence. According to experts from the Agency for strategic initiatives and Skolkovo, who are developing the Atlas of new professions 3.0, such “super professional” skills as systems thinking, working in conditions of uncertainty, programming, artificial intelligence, and environmental thinking will be important.

- Compliance with the requirements of the Federal State Educational Standard of Higher Education 3++ in pedagogical areas to the results of general cultural (in the field of universal competencies) and general professional (in the field of general professional competencies) training of students in pedagogical areas. Analysis of the content of the universal competence UC-1 “Able to search, critical analysis and synthesis of information, apply a systematic approach to solving the assigned tasks” in the category “Systemic and critical thinking” shows that the level of its development will largely be determined by information and mathematical competence. General professional competencies declare the use of information and communication technologies (GPC-2: Able to participate in the development of basic and additional educational programs, develop their individual components (including using information and communication technologies)) and special scientific (including mathematical) knowledge (GPC-8: able to carry out pedagogical activities based on special scientific knowledge)

- Compliance with professional standard 01.001 “Teacher (pedagogical activity in the field of preschool, primary general, basic general, secondary general education) (educator, teacher)”. Analysis of the labor function of the professional standard “General pedagogical function. Teaching” allows determining the structural and content components of the information and mathematical competence of the future teacher, related to ICT [13].
Based on the definition of competence as a result of mastering the relevant competencies [14-16], let us clarify the concept of information and mathematical competence: information and mathematical competence is an integrative dynamic quality of a person, characterized by the ability to use a set of information and mathematical competencies in professional activity and manifested in the readiness to apply mathematical knowledge, skills and abilities, as well as ICT tools for searching, critical analysis and synthesis of information, solving complex problems in professional and subject areas.

Taking into account the principles listed above, we will determine the composition of information and mathematical competencies of bachelors of pedagogical directions:

- able to carry out critical and systematic analysis of information, to establish cause-and-effect relationships based on mathematical and statistical methods;
- knows how to build a mathematical model of a non-mathematical problem, process or phenomenon and is able to design it using ICT;
- ready to use mathematical and statistical methods for processing and analyzing the results of pedagogical monitoring, diagnostics or pedagogical research and is able to present the indicated results with visual-graphic models (diagrams, tables, graphs, diagrams) using ICT tools;
- possesses basic mathematical knowledge and methods of information retrieval, allowing to solve applied problems in a professional and chosen subject area.

It is obvious that information and mathematical competence develops in the process of assimilating the content, mastering the techniques, methods and means of the activity itself. Thus, the process of developing information and mathematical competence should be considered as an integral system, all parts of which are interconnected and interact. From these positions, the following structural components of information and mathematical competence can be distinguished: motivational-value, cognitive-activity, personal, reflexive-creative.

The motivational and value component is a set of value orientations and needs, aimed at the formation of a positive attitude of students towards the development of information and mathematical competence. The cognitive-activity component consists of a set of mathematical knowledge, providing the solution of applied and professional problems, skills and abilities of mathematical modeling and information retrieval, critical analysis of information. The personal component includes the orientation of the personality - the readiness and ability of students to acquire, use, improve mathematical knowledge, acquire the skills of information retrieval, critical analysis of information, both individually and in conditions of cooperation and cooperation. The reflexive-creative component presupposes the student's ability to evaluate and predict his own activities, the ability to solve non-standard problems, formulate problems and find mathematical approaches to their solution, understand the cause-and-effect relationships of certain phenomena. It is associated with the analysis of the situation, the choice of means and ways to achieve the goal, the ability to predict and correct the result.

The definition of the concept, composition and structural components of information and mathematical competence formed the basis for designing a model of its formation.

The model of the development of information and mathematical competence of a future teacher includes the following components: target, meaningful, technological, effective and is presented in table 1.

**Table 1. Model of the development of informational mathematical competence of a future teacher.**

| Target component |
|------------------|
| Purpose: development of information and mathematical competence, focused on the application of mathematical knowledge, skills and abilities, as well as ICT tools for searching, critical analysis and synthesis of information, solving complex problems in professional and subject areas. |
| Tasks: |
Discussion

To assess the effectiveness of the designed model, we monitored the process of developing information and mathematical competence among bachelors in pedagogical areas of the profiles “Preschool Education” (PE-19), “Preschool Defectology” (PD-19), “Logopedia” (L-19), implying assessment students' activities in the point-rating system (table 2). The analysis was carried out by means of the discipline “Fundamentals of system analysis and mathematical information processing” using the Learning Management System Moodle platform.

Table 2. Evaluation of the effectiveness of the model for the development of informational mathematical competence in the point-rating system.

| Component | Competency component achievement indicators | Methodology | Student activity in the point-rating system |
|-----------|---------------------------------------------|-------------|---------------------------------------------|
| 4. Discussion

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Table 2. Evaluation of the effectiveness of the model for the development of informational mathematical competence in the point-rating system.
Motivational-value demonstrates a positive attitude to mastering mathematical knowledge, skills and abilities of mathematical modeling and information search, critical analysis of information - shows activity and creativity in solving applied and professional tasks that require knowledge of information and mathematical competencies

Cognitive and active demonstrates the possession of mathematical knowledge that provides solutions to applied and professional problems, skills and abilities of mathematical modeling and information search, critical analysis of information - project method - mixed learning technologies - problem-based learning

Personal demonstrates a personal focus on improving mathematical knowledge, information search skills, critical analysis of information both in an individual mode and in conditions of cooperation and cooperation - observation - project method - case method - mixed learning technologies

Reflexive and creative demonstrates the ability to evaluate and forecast their activities; - demonstrates the ability to solve non-standard problems, formulate problems and find mathematical approaches to their solution, understand the cause-and-effect relationships of certain phenomena.

- observation - project method - case method - testing
- attending lectures and practical classes; making a significant contribution to the work of the whole group (questions, discussion, speech, work at the blackboard); completing a case task in the form of a project
- solving tests, performing individual homework; control work; performing a case task in the form of a project
- working on a task in small groups; performing a case task in the form of a project
- critical thinking assessment test; performing a case task in the form of a project

Table 3 and figure 1 show the distribution of subjects in the point-rating system performance assessment and analysis of results in a five-point system in three groups.

Table 3. Distribution of examinees according to the assessment of effectiveness in the point-rating system.

| Number of points | Mark       | IMC development level | PE-19 | PD-19 | L-19 |
|------------------|------------|-----------------------|-------|-------|------|
| 86 - 100         | excellent  | high                  | 0 / 0 | 8 / 50| 3 / 13|
| 66 - 85          | good       | above average         | 11 / 69 | 3 / 19| 13 / 57|
| 51 - 65          | satisfactory | middle                 | 5 / 31 | 5 / 31| 7 / 30|
| 0 - 50           | unsatisfactory | low                    | 0 / 0 | 0 / 0 | 0 / 0|

Thus, 70% of students demonstrated rating scores corresponding to the “good” and “excellent” marks in a five-point system, which allows us to speak about a sufficient level of development of information and mathematical competence (“high” and “above average”).

To test the assumption about the predictor role of information and mathematical competence in the development of critical thinking of students, it is necessary to compare the data on information and mathematical competence with the level of development of such thinking.

To determine the level of development of critical thinking, a test was used [17]. The questionnaire contains tasks that are associated with a logical perception of the world, mathematical literacy, with the construction of hypotheses based on the presented facts and arguments, with the ability to establish cause-and-effect relationships. The author presents the test result in four ranges: 0 - 3; 4 - 6; 7 - 8; 9 - 10. In accordance with this, the level of development of critical thinking, corresponding to the first
range, we characterized as “below average”, the second - “average”, the third - “above average”, the fourth - “high”.

![Analysis of the results of rating assessment in a five-point system](image)

**Figure 1.** Analysis of the results of rating assessment in a five-point system.

To determine the level of connection and its statistical significance between the level of development of information and mathematical competence and the level of development of critical thinking, we switched to a dichotomous scale and used the Pearson $\varphi$-correlation coefficient and a four-band contingency table (table 4).

**Table 4.** Contingency table of Pearson’s $\varphi$-correlation coefficient in pedagogical research.

| Feature Y: Level of development of critical thinking | Assessment of the development of information and mathematical competence | \(\sum\) |
|---------------------------------------------------|-------------------------------------------------------------|------|
| Level of development of critical thinking is above average or high | Final mark for the course “excellent” or “good” | 32  |
| Level of development of critical thinking is average or below average | Final mark for the course “satisfactory” | 4  |
| \(\sum\) | \(\sum\) | 36 |

\[
\varphi = \frac{ad-bc}{\sqrt{(a+b)(c+d)(a+c)(b+d)}}; \quad \varphi = \frac{392}{\sqrt{36 \times 13 	imes 38 \times 17}} = 0.59
\]

Since the correlation coefficient is positive, the sign “Final mark for the course is “excellent” or “good”” correlates with the sign “Level of development of critical thinking is above average or high”. According to the table of critical values of the dichotomous correlation coefficient, we find that the coefficient is statistically significant for the first level (\(\varphi_{cr} = 0.44\)). Thus, we can conclude that the correlation between the level of development of critical thinking and the development of information and mathematical competence is statistically significant, which can be stated with a probability of 0.95.

5. Conclusion

Summing up the above, we can conclude that it is advisable to design a model for the development of information and mathematical competence of students in pedagogical areas in accordance with the key
Competencies of the future, the federal state educational standard and the corresponding professional standard. The specified model includes target, meaningful, technological and effective components. Clarifying the concept of information and mathematical competence, emphasis should be placed on its manifestation in the readiness to apply mathematical knowledge, skills and abilities, as well as ICT tools for searching, critical analysis and synthesis of information, solving complex problems (Complex Problem Solving) in professional and subject areas. The use of statistical methods makes it possible to establish a correlation between information and mathematical competence and the level of development of critical thinking and to formulate a hypothesis about the predictive role of BCI in the study of the processes of formation and development of critical thinking. This determines the prospects for further research in the field of designing a model for development of information and mathematical competence as a predictor of critical thinking in the higher education system.

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