Development of professional competencies of future technical university specialists through professionally oriented teaching of mathematics

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ABSTRACT: In the modern conditions of globalisation, the prospects for the organisation of professionally oriented mathematics education in the Republic of Kazakhstan is one of the most important problems for improving the quality of technical education in the state. The purpose of the study was to analyse and implement a methodology aimed at increasing the readiness of future specialists of technical universities to form professional competencies. The methodology included analysis, comparison, systematisation and experimental methods, and was aided by mathematical statistics. The research was conducted at *Korkyt Ata* Kyzylorda University, Kazakhstan, which made it possible to develop methodological tools to improve the training of specialists through professionally oriented teaching of mathematics. In the article, important pedagogical conditions are highlighted, such as a variety of forms of educational activity, activation of independent work and the use of digital technologies - all of which are conducive to the formation of the required competencies.

INTRODUCTION

Higher education in the Republic of Kazakhstan in the 21st century requires a reconstructive approach to the implementation of professionally oriented education. This approach is conditioned upon the active process of informatisation of society. Also, the successful implementation of such education requires finding new ways to improve the educational process, developing and applying modern innovative methods, forms and technologies for the organisation of professionally oriented mathematics education [1].

The relevance of this issue is grounded in the current insufficiency of theoretical and methodological development of modern methods of organising professionally oriented training of future specialists of a technical university who have to develop professional competencies during their studies. Hence, the need for the introduction of computer technologies into the educational process, and specifically, the widespread introduction of advanced information technologies in the process of professionally oriented mathematics education in Kazakhstan [2].

According to O'Sullivan, the construction of a high-quality training system for future specialists of a technical university should be implemented through the development of a system of professional competencies [3]. A higher educational institution, in particular a technical one, should be focused on professionally oriented teaching of mathematics as a fundamental discipline in the professional training of highly qualified specialists who are competitive in the labour market. However, the method of development of professional competencies has not been sufficiently addressed by researchers. The issue of building a clear structure of the methodological system of teaching mathematics needs to be resolved.

Exploring the issues of the development of professional competencies of future specialists of a technical university, Ozhybaeva and Nurmukhanbetova identified the mathematical skills that future specialists should possess; namely, mathematical thinking, argumentation, communication and modelling, effective solution of mathematical problems, the ability to represent data, operate with mathematical constructions and actively use mathematical tools [4].

The researchers propose to combine the designated components into three classes of competencies: reproduction, definitions, calculations, the ability to reproduce mathematical constructions, the ability to master the definitions of mathematical objects; ensuring the structuring and integration of material for solving problems; providing mathematical thinking, generalisation and insight, but do not provide methods for their development [4].

Aitbaeva and Shaihozova consider that teaching mathematics should be carried out by fulfilling two main tasks; namely, the presentation of mathematics as a basic science and the active use of mathematical techniques in the development of professional competencies [2]. However, the study supports the opinion of researchers that one of

the main problems of the quality of technical education is the insufficient practical implementation of the principle of professionally oriented teaching mathematics, which can be improved by strengthening the components of the methodological system used in practice. It is necessary to specify the components of the methodological system that are not considered by scientists [2].

According to Palais, the solution to the problem of the development of professional competencies of future specialists is becoming relevant and needs to be solved [5]. The researcher considers the opinion that the professional direction and motivation for fruitful work allow a specialist to ensure their realisation in line with professional activity and self-improvement. That is why the priority area of improving the quality of professional training of future specialists of a technical university is the development of professional competencies, which has not been fully considered. The problem of studying professionally oriented mathematics education is complex and requires an immediate solution.

The following tasks that need to be solved in the process of conducting the study are highlighted:

- to analyse the experience of the development of professional competencies of future specialists in technical universities in Kazakhstan;
- to develop and verify the components of the readiness of future specialists in technical universities in Kazakhstan for the development of professional competencies;
- to approbate methodological tools aimed at developing the readiness of future specialists in technical universities in Kazakhstan to develop professional competencies through professionally oriented training.

METHODS

The research process consisted of theoretical (analysis, comparison, systematisation, classification, generalisation of theoretical data) and practical (experiment: ascertaining, formative and control) stages.

The theoretical stage, apart from the above-mentioned processes, included also modelling of the process of diagnosing the levels of organisation of professionally oriented mathematics education using the developed components of readiness of future specialists; and the investigation of the existing methodology for the organisation of professionally oriented training of future specialists of technical education in universities in Kazakhstan.

The practical stage consisted of the implementation of the selected methodology for the organisation of professionally oriented mathematics education with outlined readiness components. This implementation was carried out at *Korkyt Ata* Kyzylorda University in Kyzylorda. To ensure the representativeness and reliability of the sample, the features of group formation, age and gender of respondents were determined. The research collection was carried out by pairwise selection. The sample consisted of 86 respondents whose age category was in the range from 18 to 21 years. The control group included 62 respondents and the experimental group 24 participants. There were no significant differences between the experimental and control groups before the experiment. The established groups included respondents who studied in the same course and educational training programme. The establishment of groups - experimental and control - was carried out by analogy with one another for all the studied signs, which allowed for comparative observation. The results of the experimental studies were evaluated at high, average and low levels. The experiment was conducted during the 2023-2024 academic years.

To increase the level of readiness of future specialists at the ascertaining stage of the experiment, the following components of readiness were identified; namely, motivational, cognitive-operational, and reflexive. Also, at this stage, the levels of readiness were determined.

Using a competence-based approach, the necessary methodological tools were selected to ensure the high-quality implementation of professionally oriented training for the outlined components of the readiness. Pedagogical conditions have been created; technological models have been developed; concepts of the information educational environment of technical universities have been used; the necessary methodological tools have been selected to ensure high-quality implementation.

To determine the levels of development of the motivational component, the methodology for studying motivation for learning at a university by Ilyina was used [6]; the level of formation of the cognitive-operational component was carried out using testing in the discipline *Mathematics*; the reflexive component was checked by students solving individual tasks aimed at developing self-reflection. Based on the results of the ascertaining stage, a methodological toolkit was selected to improve the levels of formation of professional competencies of future specialists of a technical university. At the formative stage of the study, the obtained toolkit was checked during the study of the special course *Methodology for solving professionally oriented problems in mathematics*, consisting of two modules developed by one the authors of this article.

The content of the first module includes topics that reveal the essence of professionally directed tasks and their role in the development of professional competencies. For example, on *differential calculation* such topics were proposed as *gradient, directional derivative, extremum and the largest, smallest value of a function of several variables* with

the following tasks: to calculate the gradient and derivative for a given function; to solve a technical problem with an explanation in terms of applying knowledge on *differential calculation*. Next, the task was checked and evaluated. In order to avoid cheating in the test paper, some questions of independent assignments were included. The second module was devoted to a variety of methodological components aimed at the high-quality organisation of professionally oriented training.

After receiving the results of the study at the ascertaining and formative stages, a control stage was carried out. The obtained data were processed according to the Pearson chi-square criterion, they were generalised, conclusions were made and prospects for further research were outlined.

RESULTS

The educational course *Mathematics* in technical universities in Kazakhstan is designed to ensure stable possession of a system of mathematical knowledge aimed primarily at: general development of students, practical activities, acquisition of competencies in disciplines of a related cycle; namely, physics, chemistry, technology, continuation of specialised education. The general educational goals of mathematics include familiarisation of students with scientific research methods, such as analysis, synthesis, induction, analogy. Students at *Korkyt Ata* Kyzylorda University do not study numerous sections of mathematics in full, which are not related to the disciplines of the professional cycle, including theory of differential equations, functional analysis, applied statistics, decision theory [7].

As currently required, the use of digital learning technologies in the context of professionally oriented mathematics education is becoming important in the field of technical education. That is why the solution to this problem should be considered as one of the necessary conditions for the development of professional competencies of future specialists of technical universities.

In the process of studying the special course *Methods for solving professionally oriented problems in mathematics*, pedagogical conditions have been implemented that most effectively affect the process of providing professionally oriented mathematics education in the process of forming the professional competence of future specialists of a technical university; namely:

- variety of forms of educational activity;
- activation of independent cognitive activity;
- use of digital technologies;
- use of professionally oriented tasks.

The components and criteria of its organisation; namely, motivational (value criterion), cognitive and operational (knowledge-operational), and reflexive (subjective), have been identified for the implementation of readiness of future specialists of higher education institutions of technical profile to form professional competencies.

Motivational (value criterion) - consists of goals, motives, needs, values and professional interests. The essence of the motivational component is to implement a system of motives and needs in organising the process of professionally oriented training of future specialists, encouraging them to study on the basis of autonomy, stimulating and supporting the activity of students at a certain level. The motivational criterion is designed to reflect the attitude of students to the learning process, to use technologies that promote the assimilation of knowledge and digital learning tools. The motivation of students is accompanied by utilitarian and practical motives, it has to acquire personal significance, which is able to turn the goals and objectives outlined by the teacher into internal needs.

Cognitive-operational (knowledge-operational) is manifested in the presence of knowledge: skills and abilities in mathematics for their implementation in practice.

Subjective (reflexive) - manifests in the ability to analyse psychological characteristics and professional inclinations, to predict and control the results of learners' activities; the ability to mobilise their own potential, mobilise creative energy, the ability to express themselves, engage in self-development and self-improvement. The criterion reflects the level of formation of professional competencies in respondents.

To determine the levels of development of the components of the readiness under study, a preliminary stage of the experiment was conducted. In the control group, which was trained using the generally accepted methodology, readiness to develop professional competencies was tested for three components of readiness when studying a mathematical course. The level of development of the motivational component was carried out using the methodology for examining motivation for studying at a university by Ilyina; cognitive-activity - by conducting multi-level testing in *Mathematics* to assess the professional competencies of students [6]. The development of the reflexive component was checked by students solving individual tasks aimed at developing self-reflection.

The results obtained at the ascertaining stage of the experiment for the control group were processed and are presented in Figure 1.

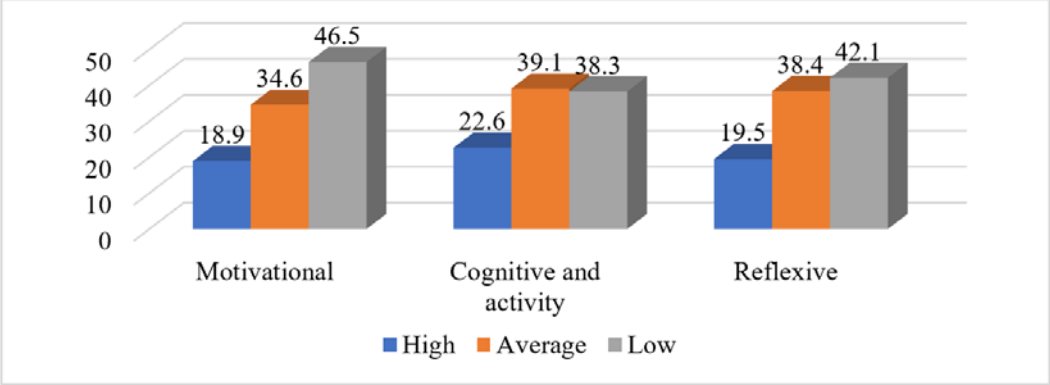

Figure 1: Readiness level of the control group at the ascertaining stage of the experiment.

The results obtained at the ascertaining stage of the experiment for the experimental group are presented in Figure 2.

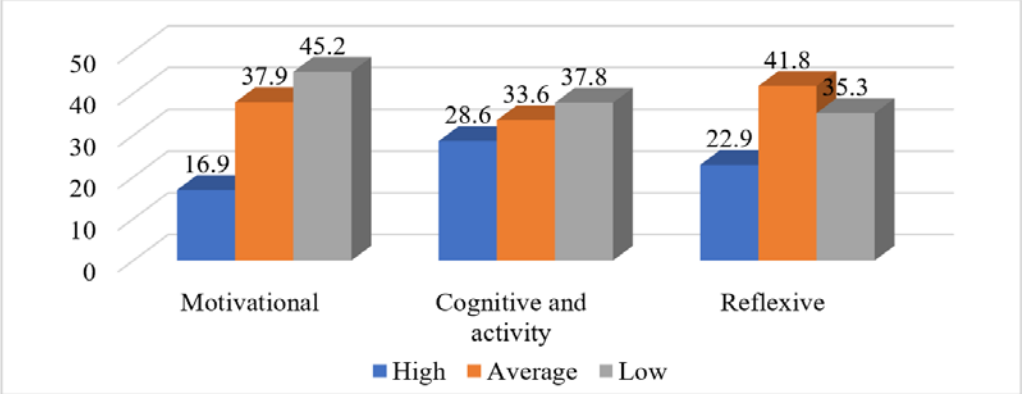

Figure 2: Readiness level of the experimental group at the ascertaining stage of the experiment.

The data obtained at the ascertaining stage of the experiment led to the conclusion that the respondents of the control and experimental groups were at a low and medium level of readiness for the formation of professional competencies. Such results indicate the need to develop a methodological system for teaching mathematics based on professionally oriented training. During the experiment, methodological features of the implementation of such training and the corresponding methodological techniques reflected in the current teaching programme of the course *Mathematics* and the special course *Methodology for solving professionally oriented problems in mathematics* at *Korkyt Ata* Kyzylorda University were identified.

The following criteria were used in the selection process:

- general didactic - aimed at ensuring scientific and professional consistency, connection of theory with practice, computer and *traditional* visualisation of educational information, awareness, activity and independence of students in the assimilation of knowledge;
- general psychological - designed to ensure proper motivation of students in the organisation and implementation of professionally oriented study of mathematics, conducting pedagogical and computer support of the educational process;
- methodical - ensuring the regularity, *algorithmicity*, phasing and consistency in the assimilation of educational information with the provision of feedback between teachers and students, a unified approach to the implementation of professionally oriented mathematics teaching;
- technical - qualitative use of technical means of education in the implementation of professionally oriented mathematics education;
- ergonomic - focused on providing functional comfort at work.

In order to implement the developed special course, the formative stage of the experiment was carried out. The authors proposed the solution of professionally oriented tasks for the development of motivation to study mathematics; namely:

1) The auditorium has lighting, the devices of which consume 300 watts in the complex. Would costs be reduced by 30% if the existing lighting was replaced with energy efficient fixtures? How many watts can be saved during the day by using energy-saving devices? Students are offered to solve the problem in several ways and submit them in writing.
2) It is necessary to manufacture a closed cylindrical tank, the total surface of which is S. Specify the height of the tank if its volume was the largest.

In general, the study proposes 44 author-developed professionally oriented tasks. The implementation of the meaningful criterion consists in determining the available knowledge, including the types, methods and techniques that affect the organisation of the process of professionally directed learning in teaching mathematics, the implementation of ways to optimise and intensify them using digital technologies. It is proposed to increase and diagnose the levels of organisation of the readiness of future specialists of a technical university to develop professional competencies with the help of professionally oriented mathematics training according to a meaningful criterion according to the methodology of posing problematic issues and professionally oriented tasks during the study of mathematics.

The implementation of the operational criterion is to instil in future specialists the skills of using techniques and methods of professionally oriented training on the way to the development of professional competencies. The methodology for diagnosing the content and operational criteria consists in the development of the special course *Methods for solving professionally directed problems in mathematics*. It is also proposed to complete original assignments with professionally oriented content.

The study proves that mastering mathematics in technical universities should develop intellectual abilities, analytical and technical thinking, intuition, mathematical culture; students should assimilate mathematical knowledge and acquire skills necessary for the study of related professional disciplines; and be able to apply basic mathematical methods for the analysis and modelling of processes and phenomena of professional activity. The reflexive component is manifested in the ability to analyse psychological features and professional abilities, to predict and control the results of activity. The criterion reflects the level of development of respondents' skills to solve professionally oriented tasks and carry out self-assessment of their own activities.

When determining the levels of readiness of future specialists, attention is focused on the levels; namely: high, average and low. The results for the control group obtained at the formative stage of the experiment after the implementation of the outlined methodological system are presented in Figure 3.

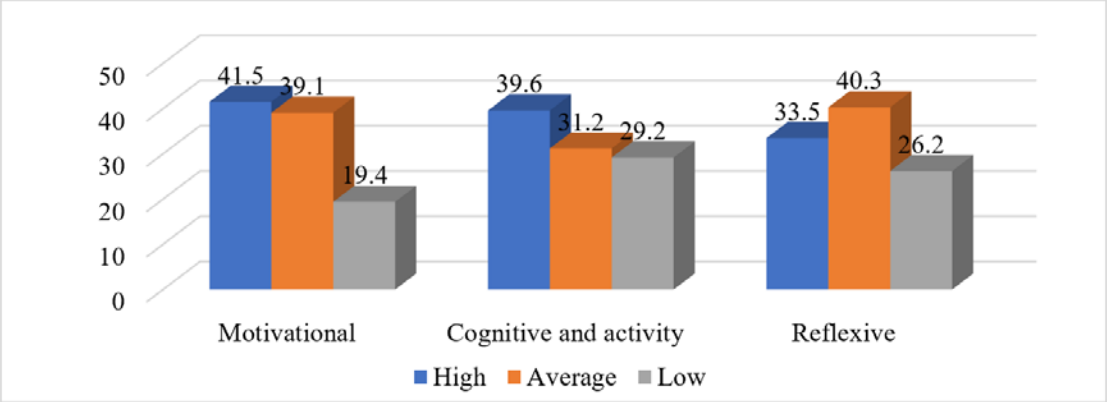

Figure 3: Readiness level of the control group at the formative stage of the experiment.

The results of the implementation of the methodological development at the formative stage of the study in the experimental group are presented in Figure 4.

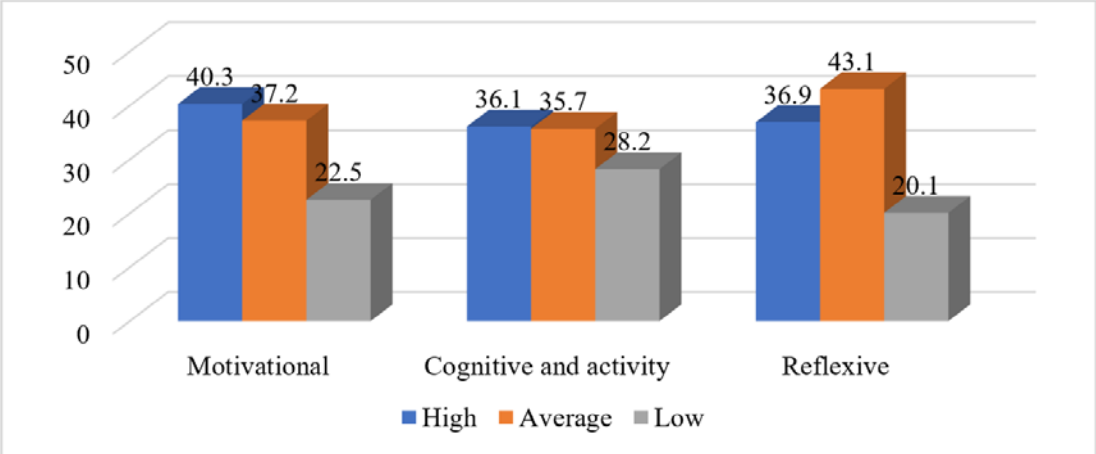

Figure 4: Readiness level of the experimental group at the formative stage of the experiment.

According to the data obtained during the analysis of the results of the implementation of the special course *Methods for solving professionally oriented problems in mathematics* in the experimental group, it was found that in order to ensure the development of professional competencies of future specialists of technical universities in Kazakhstan,

it is extremely important to solve the issue of professionally oriented teaching mathematics, which was solved during the experiment.

The control stage of the experiment was carried out, at which the analysis of the results of the conducted experimental research was carried out, and the effectiveness of the proposed methodology for the development of professional competencies was assessed. The use of parallel computing in solving problems of numerical methods was carried out using methods of mathematical statistics. In the study, the samples are random, independent and subject to the normal distribution law. The experimental data were processed according to the Pearson chi-square criterion. In processing the data of the ascertaining experiment, no significant differences were found in the respondents of the experimental and control groups. However, differences were noted in the experimental and control samples, as well as differences in the control sample before and after the formative experiment.

DISCUSSION

The development of a modern dynamic society dictates updated requirements for a person who must have technical and innovative thinking abilities, and be able to solve professionally oriented tasks in professional activity. That is why the high-quality organisation of professionally guided mathematics education is one of the most pressing issues widely discussed by scientists around the world.

Higher technical education in Kazakhstan should be aimed at training competent specialists capable of reacting in a changing socio-economic society, searching for non-standard solutions. Ensuring the development of a high level of professional competence of future mathematics specialists is the key to their competitiveness in the labour market [8].

Exploring the issues of the relationship between the fundamental and professional orientation of teaching mathematics, Stokking et al concluded that such a task is extremely difficult [9]. The researchers believe that ensuring students' interest in studying mathematics and determining its role in technical education depends on the teacher's experience, and the availability of professionally oriented textbooks and problem books in mathematics, which are currently lacking. All this affects the content of education, which is based on a formal and logical presentation of scientific knowledge isolated from technical activities. The expressed approach is considered correct and requires diversity in the training of future specialists of a technical university by solving the issue of the process of forming a graduate's readiness to apply professional competencies; namely, in the process of studying the courses *Mathematics* and *Methods of solving professionally directed problems in mathematics*.

Examining the variety of competencies of future specialists of the technical university, Asaduzzaman and Asmatulu identified subject competencies that are aimed at specific attributes of the field of study and are formed as a result of competency-based learning of the relevant discipline and determine the subject aspect of the graduate's competence [10].

The outlined approach is considered correct because the designated subject competencies should be developed in the context of professionally oriented training as done during the special course *Methods for solving professionally oriented problems in mathematics.*

Exploring the issues of the implementation of the professional orientation of teaching mathematics to future specialists of a technical university and the structure of professional competence in the field of mathematics, Bergmann identified a system of didactic and methodological resources of professional orientation for the formation of outlined competence of students [11].

According to Abualrub et al, professional-pedagogical and professional-psychological orientation in the development of personality are interrelated and are the key to the development of not only professional competencies, but also professional knowledge [12]. It is worth agreeing with the opinion of researchers highlighting the following components of professionally oriented education; namely, persistent motivation to study mathematics and subjects of the mathematical cycle; development of professional knowledge and interests, and mastering the methodology for solving professionally oriented tasks; providing future specialists with knowledge and skills for self-realisation and self-improvement in the context of their own professional activities.

O'Sullivan actively investigated the development of the issue of the professional direction of the personality of a technical specialist, as a result of which components of their readiness to carry out professional activities were identified; namely, personal (formation of needs, desires, interests, ideals, beliefs, worldviews, value orientations of a specialist); reflexive (ensuring the development of self-esteem for further persistent improving their professional competencies, striving to improve professionally); and procedural (consisting in the development of professional competencies as a guarantee for implementation in the professional field) [3]. However, the results described above contradict this, since in the system of development of professional competencies of future specialists of a technical university in the process of professionally oriented mathematics education, the following components should be distinguished: motivational, cognitive-operational, and reflexive. The following skills are highlighted that future specialists should possess in the process of professionally oriented mathematics education: organisational skills, professional, communicative, projective, reflexive and creative.

Studying the competence-based approach to training with the application of a professionally applied orientation among specialists of a technical university in Kazakhstan, Scharle and Szabo came to the conclusion that the essence of this approach is the independent acquisition of knowledge, the application of a creative approach in the process of solving non-standard tasks [13]. Regarding the results obtained in this study, the use of the proposed approach may be correct; namely, because there will be a correspondence between mathematics and the disciplines of the technical cycle; determination of the elements of the content component of training that ensures the development of competencies and diagnostics of the effectiveness of the outlined process; identification of the features of the procedural component, which is the key to the implementation of competence-oriented training of future specialists of a technical university; ensuring the organisation of teacher training for work in a competency-based approach [13].

The results of this study confirm that the basis for the professional training of future specialists of a technical university is mathematical knowledge, which students receive in the process of studying mathematics, as a key to mastering disciplines of a special cycle. That is why future specialists should be focused on acquiring professional competencies for their qualitative use in future professional activities.

Considering the above-mentioned features of the implementation of professionally oriented mathematics education in universities of the technical direction in Kazakhstan in the study, the following areas of mathematical training are proposed:

- reorganisation of the educational process taking into account the specifics of education in a technical university;
- updating the curriculum content;
- a variety of forms of educational activity;
- activation of independent cognitive activity;
- use of digital technologies;
- use of professionally oriented tasks.

CONCLUSIONS

The study showed that high-quality training of future specialists of technical universities requires professionally oriented training, with an emphasis on the formation of professional competencies. This is possible through content forecasting and the introduction of modern technologies and methods, especially in teaching mathematical disciplines. To do this, teachers need to improve their skills, develop creativity, social adaptation and responsibility.

It is determined that the level of readiness of students to form professional competencies in mathematics is at low and medium levels, which requires the development of methodological tools. During the experiment, the motivational, cognitive-operational and reflexive components of readiness were identified, diagnostics were carried out and a conclusion was made about the need to update the methods.

The developed special course *Methods of solving professionally directed problems in mathematics* showed positive results among experimental groups. The results confirm the effectiveness of the proposed methods, and the educational policy of Kazakhstan should contribute to the renewal of the training of future specialists.

Future research should focus on the formation of mathematical and general scientific competence, the integration of mathematics and computer science, as well as the use of digital resources to improve professionally oriented learning.

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