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Methodological Support for Professional Development of Physical-Mathematical Sciences Teachers, Aimed at Forming the Project-Technical Competency of Technical University Students

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Abstract

The necessity of forming a project-technical competency of students in technical universities is due to the transition of the industrial areas to science-intensive technologies and the need for active involvement of professionals in their elaboration, implementation, and technical calculations. In this process, a key role should be given to a teacher of physical and mathematical disciplines, his readiness for the process of the students' project-technical competency formation in the study of these disciplines. In this regard, this article actualizes the problem of developing methodological support for professional development of physico-mathematical sciences teachers, contributing to their choice of optimal content and technologies for teaching mathematics and physics, aimed at forming the project-technical competency of technical university students. The article materials may be useful both for teachers of physico-mathematical disciplines, and for teacher education university students—future teachers of physico-mathematical disciplines.

Keywords: professional development, physics and mathematics, teachers, project-technical competency, technical university students

1. Introduction

The project-technical competency of a future technical specialist is defined as a complex integral system of his personal and professional qualities, characterizing the degree of (self) identity development and reflecting the synthesis of technical and designing knowledge, abilities, skills, intellectual abilities, action programs, value orientations aggregate, motives and professional self-improvement needs of the student, personal attitude to the subject of activities, which are then detected in the project-technical competence within the activity-relevant aspects (Ageeva & Cotov, 2006; Miller, 2008; Levina et al., 2015).

In the content of the project-technical competence we have identified the following competencies formed in students when learning mathematics and physics:

- Motivation of studying mathematics and physics as means of forming the project-technical competency; persistence in professional training; educational activity and independence; confidence in achieving the goals set in professional activities; willingness to start from scratch and develop a new direction;

- Competencies in the acquisition of knowledge; mastery of the system of physico-mathematical and interdisciplinary knowledge, abilities and skills needed in handling applied problems; efficient use of physical and mathematical knowledge in practice; ability to organize the relationship of knowledge and systematize it; mastering the skills of project activities, ability to systematize scientific information, to represent it in the form of annotations, reports, presentations;

- Ability to transfer the gained physico-mathematical knowledge, abilities and skills to meet the challenges of an applied, interdisciplinary character and perform project tasks; ability to effectively and efficiently apply knowledge to new situations; updating of knowledge in solving practice-oriented and professionally-oriented physical and mathematical problems, project type problems; ability to use the algorithms in the process of self-study of the main structural elements of the system of scientific knowledge; ability to apply cognitive capacities in solving project problems at the level of analytic-synthetic activity; demonstrate willingness to continuous updating of knowledge and skills; ability to see problems in various areas of knowledge and on this basis to formulate the goals, objectives of the project, ability to hypothesize when planning a project; independently select the ways and means of solving the problem; ability to analyze the resources to implement the project, independently select the necessary knowledge, methods and choose the necessary tools; ability to plan in detail all the stages of the project implementation, teamwork proficiency and ability to argue and defend their point of view; ability to interpret the obtained results in accordance with a particular theory; proficiency to process and present the results of the project implementation, to assess their technical rationality and economic efficiency, possible errors, committed in the course of development;

- Ability to introspect, objectively self-estimate, self-criticize; ability to express one's own point of view; ability to adequately assess own performance in achieving the objectives of learning, changes in own personality, a willingness to overcome difficulties, identify and eliminate their causes, aspiration to self-improvement, self-realization, awareness of the need for continuing education, self-education and self-development for a successful professional activity (Zaripova, 2011; Zaripova et al., 2014, 2015); Khanmurzina et al. (2015); Levina et al. (2015).

The essence of the project-technical competency formation in students of technical universities in the learning process of physico-mathematical sciences is to acquire physico-mathematical and special knowledge, skills and ways of activity, allowing students to solve technical problems, to see and solve problems happening in industrial practice, to carry out project tasks, what contributes to the realization of their intellectual potential in future professional work (Zaripova, 2014; Kozhuharova & Branenkova, 2010).

The content of teaching mathematics and physics, aimed at forming the project-technical competency of future technical specialists, should consider the following requirements: it is necessary to preserve the integrity and fundamentality of the disciplines themselves, forming a scientific and logical thinking of students; the content of teaching physics and mathematics disciplines, in addition to the fundamental systemically important scientific knowledge, should reflect the basic objects of professional activity of the future technical specialist, consider his action system as that of a professional; the content of teaching mathematics and physics to future technical specialists should be directed to the formation of their logical and technical thinking necessary in their future professional activity, requiring the formation of the designing and forecasting skills and competencies; there should be organized and consistent reflection of interdisciplinary relations in teaching mathematics and physics content, which reveal other areas of their application and connection with the prospects of innovative production; the content should show the possibility to apply mathematics and physics in the process of modeling and designing when solving profession-oriented physico-mathematical problems (Shichkov, 2013; Zaripova, 2014; Sakhieva et al., 2015; Mukhametzyanova & Shaidullina, 2011; Ivanov et al., 2015; Khairullina et al., 2015).

In this process, a key role should be given to the teacher of physico-mathematical disciplines, to his readiness for the process of forming the project-technical competency of students in the study of these disciplines. Therefore, this actualizes the problem of developing methodological support for training and professional development of physico-mathematical disciplines teachers, aimed at the formation of the project-technical competency of technical university students.

2. Materials and Methods

2.1 The Aim of the Experimental Work

The aim of the experimental work was to develop methodological support for retraining and professional development of physico-mathematical disciplines teachers, contributing to the selection and optimal content of technologies to teach mathematics and physics, aimed at forming the project-technical competency of technical university students.

2.2 Structure of the Methodological Support

The developed methodological support for retraining and professional development of physics and mathematics teachers, contributing to their choice of the optimal content and technology for teaching mathematics and physics, aimed at creating the project-technical competency of technical university students, includes a

professional development program for faculty members "The competence-based approach in higher education in the formation of the project-technical competency", training manuals for students, recommended practices on the project-technical competency formation in students—future petroleum engineers, diagnostic tests, tests for control and self-control.

2.3 Components and Readiness Criteria of Teachers for the Process of Forming the Students' Project-Technical Competency

Teachers' readiness for the process of forming the project-technical competency of students has motivational, cognitive and operational components. Accordingly, the criteria have been developed with the same name, which allowed assessing the level of teachers' readiness:

1) Motivational, characterized by the formation of the beliefs in the necessity to form the project-technical competency of students.

This criterion includes the following indicators: the presence of an internal positive motive to organize educational activities on the competence-based approach, presence of cognitive interest in innovative teaching practice, professional problems solution, the awareness of the need for continuing education, self-education and self-development for successful pedagogical work with students.

2) Cognitive, characterized by the presence of professional knowledge required for the formation of the project-technical competency, diagnostics of students' abilities and readiness for the formation and application of the competencies.

This criterion includes the following indicators: the effectiveness of the use of knowledge in practice, systemacity of knowledge in conceptual pedagogical bases of forming the project-technical competency, application of knowledge in the competence-oriented educational process.

3) Operational (activity), including professional skills and competencies for solving professional problems associated with the introduction of the competence-based approach, ability to design the formation of certain competencies and competence as a whole.

This criterion includes the following indicators: formation of professional skills; focus on creativity in the competencies formation process; mastering new technologies and ways of forming the project-technical competency of students.

The cognitive criterion assessment was carried out by a testing method, the motivational and the activity ones—by methods of complex surveys, questionnaires, interviewing, and discussions. The levels were determined by the card of readiness (Table 1).

Table 1. The formation level card of teachers' readiness

	Low	Average	High
Motivational	Characterized by weak motivation to form the project-technical competency, restructure the system of assessing the results of educational activities, by reluctance to be engaged in continuous self-education for performing effective professional activity	Characterized by created motivation to form the project-technical competency, restructure the system of assessing the results of educational activities, by lack of interest for using the competence-based approach in solving professional problems, by fragmentary nature of own self-education.	Characterized by a responsible attitude to the formation of the project-technical competency, the restructuring of the assessing system, by a sustainable positive motive to solve the corresponding professional problems, high requirements to their own self-improvement for successful realization of the given work.
Cognitive	Characterized by insufficient professional knowledge for the process high-quality implementation in forming the project-technical competency and the subsequent thereof weak awareness of their students' abilities.	Characterized by sufficient professional knowledge for the proper implementation of the project-technical competency formation process, for work with students, however, by insufficient awareness of the students' professional abilities.	Characterized by a wide range of professional knowledge for effective introduction of activities in the educational process for forming and evaluating the project-technical competency.

Operational	Characterized by insufficient professional skills and, consequently, low activity for forming and evaluating the students' project-technical competency	Characterized by developed professional skills for forming the project-technical competency according to the elaborated teaching aids	Characterized by developed professional skills, a creative approach to the formation and evaluation of the project-technical competency

3. Results

Our elaborated program for professional development is designed for targeted training of university teachers to form and evaluate the project-technical competency of students when training them for future professional activity.

The objective of the training course program is to develop teachers' understanding of the project-technical competency and the professional competencies based on it, the competence-based approach in education, technologies to form the competencies.

The course lasts 72 hours, including 46 hours of classroom work and 18 hours of practical work. Although the program consists of two main sections (lectures and practical classes), each of these sections includes academic training and independent practice of the course participants. The program had options on various parameters: position, work experience, individual needs, et cetera.

As a result of professional development training at this course the teacher should be able to:

- Identify the actual composition of the graduates' competency;
- Carry out systematic implementation of the competence-based approach in education programs of academic disciplines and practices;
- Devise technologies to develop and form the necessary competencies by means of practice-based disciplines;
- Estimate the competencies development level of students and graduates;
- Be able to elaborate diagnostic materials to assess the learning outcomes of students on the basis of the competence-based approach;
- Evaluate readiness of university graduates within the current, phased and final certification.

Table 16 shows the results of diagnosing the level of the teachers' developed readiness to form the project-technical competency before and after the professional development training courses.

Table 2. The level of the teachers' readiness for forming the project-technical competency diagnostic results (%)

Level	Before	After
High	16	65
Average	32	32
Low	52	3

The analysis of the obtained results shows that the readiness development for forming the project-technical competency of the course participants significantly changed after the introduction of the methodological support, which was confirmed by the statistical processing of the results by the Wilcoxon shifts method. Shifts in the affirmative responses of teachers following the course are valid. Hence, the content of the program contributed to increasing the level of teachers' readiness to form the project-technical competency of the students in studying the disciplines of mathematics and natural science cycle.

4. Discussions

The analysis of the survey of teachers' data revealed their insufficiently clear idea of how to form the project-technical competency of students in the study of physico-mathematical disciplines. Many teachers understand this process intuitively at the level of life and teaching experience. The complexities involved in forming the project-technical competency in teaching mathematics and physics, are primarily due to the fact that the majority of mathematics and physics teachers—are not graduates of technical, but pedagogical universities,

or physical and mathematical departments of universities. Ability to present the mathematical (physical) material in conjunction with other natural-science and technical disciplines will require from mathematics (physics) teachers of certain efforts on expansion of their outlooks. Cooperation of teachers of various chairs is particularly important. Besides, the teachers are not proficient in the required degree of knowledge about the competence-based approach, methods and technologies to form competencies, essential and substantive characteristics of the competencies evaluation technology, the evaluation criteria in training students for their professional activity. Intuitively, teachers feel the need for additional knowledge on the application, practical implementation of the competence-based approach, practical technologies for forming professional competencies of the students, including the project-technical competency; however, they have no systematized knowledge of this pedagogical phenomenon.

The analysis of the data showed that the teachers do not have a clear idea about the nature of the project-technical competency, understand it intuitively, relying on the life and teaching experience. They define it either too broadly, or, on the contrary, specifically, reflecting only a few individual aspects of the concept content "the project-technical competency." In addition to the findings mentioned above, the questionnaire got other results as well, which are less significant. Thus, the majority (72%) of the teachers, on the basis of their own experience, stated that the young men's level of the project-technical competency is higher, than that of girls. 21% of the teachers (mostly women) disagreed with this statement. Concerning the period of the most successful and active forming the project-technical competency, the teachers especially note the second and third years of study in higher school (57%), which is explained both by the sufficient amount of the accumulated basic knowledge, and the beginning of studying the specialized disciplines. Although 23% allocated as an important step of forming the project-technical competency the period for writing the graduation project as a period close to the ultimate goal of studies. It was interesting to analyze and compare the responses of teachers and students to the question about the factors that influence the formation of the project-technical competency most in the learning process at the university. The following results have been obtained.

Based on the interviews and survey results of the faculty we have identified factors that block the introduction technologies to form the project-technical competency as a basic professional competency, namely:

- Teachers' professional unpreparedness for the formation of students' project-technical competency;
- Lack of adequate guidelines for forming the project-technical competency in higher technical school;
- Psychological unreadiness of teachers to introduce innovative technologies in the educational process.

Most teachers do not consider it necessary when teaching their discipline to set other than educational goals, including the goals of forming the project-technical competency of the students. A part of the teachers (30% the respondents) recognize the need to form professionally important qualities of the future petroleum engineer, but they believe that their fundamentals are formed automatically in the education process, and to achieve a high level of development is only possible as a result of immediate professional activities, and as long-term. We believe that the teachers should in their professional activities proceed from the fact that the formation of the project-technical competency in the future engineers does not happen automatically. The project-technical competency of the students should be formed purposefully and systematically in the process of studying disciplines of not only the special, but also the general education cycle.

5. Conclusion

Thus, the need for developing and implementing methodological support for professional development of physico-mathematical disciplines teachers of higher technical school—was caused by the fact that, based on the analysis of the survey data of teachers, there has been identified their insufficiently clear understanding of the nature of the formation of the project-technical competency of students in studying physico-mathematical disciplines. The presented methodological support for retraining and professional development of physico-mathematical disciplines teachers, contributing to their optimal content and technologies selection in teaching mathematics and physics, which are aimed at forming the project-technical competency of technical university students, includes a professional development program for faculty members "The competence-based approach in higher education: the formation of the project-technical competency", training manuals for students, recommended practices on the formation of the project-technical competency of students—the future petroleum engineers, diagnostic tests, tests of control and self-control.

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