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Teaching Physics: Identification of the Dynamics of the Development of Criteria Indicators of Functional Competence

Aksholpan Serikkyzy [a, *], Aliya Sarybayeva [a], Aknur Batyrbekova [a], Nurdaulet Shektibayev [a]

[a] Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Republic of Kazakhstan

Abstract

Today, the teacher faces many practical problems and problems related to improving the quality of education. Solving these tasks requires the formation of functional competence, which is an important indicator of the professional growth of a future teacher. However, it emphasizes the fact that the problem of forming the functional competence of a future teacher in certain subjects has not yet been completely solved. The purpose of the research work is to identify the main factors and pedagogical situations in the formation of functional competence of students in the process of teaching physics lessons, to prove their effectiveness based on the dynamics of growth of indicators of functional competence. The study used methods such as direct and indirect educational observations, tests, surveys, qualitative and quantitative analysis, as well as mathematical and statistical data processing. The research made it possible to determine the component part of the student's functional competencies in physics, to determine the pedagogical conditions and external and internal factors necessary to achieve maximum success of the student's functional literacy in the field of studying the natural science cycle of the University. In addition, the structural components and criteria indicators of functional competencies are determined, the dynamics of the growth of indicators through pedagogical experiment is shown. The results of the study will serve as a great scientific document for subsequent research in the field of functional competence, and will also have a huge impact on the development of science and technology, if viewed from the side of professional activity.

Keywords: functional competence, functional literacy, teaching physics, future physics teachers, criteria indicators.

1. Introduction

The era of globalization requires the improvement of the methodology for the formation of competitive specialists in the education system aimed at the development of all human activities,

* Corresponding author
E-mail addresses: aksholpan.serikkyzy@bk.ru (A. Serikkyzy)

in particular, the sphere of human capital. Professional competence approach is one of the priority systems for the implementation of these needs (Hamaidi et al., 2021).

Education, in general, has a serious impact on the socio-economic, socio-cultural development of the state, its position in the world, its integrity and security. It is believed that the deterioration of the work of schools, pedagogical institutions, and the system of professional development of teaching staff, which is a direct generating factor of spiritual and cultural reproduction of society, quickly leads to a consistent breakdown of the entire continuous system of education.

Therefore, the education system, and above all, the secondary education system, needs teachers who can effectively solve problems to ensure the quality of education in a rapidly changing modern world (Ramankulov et al., 2020).

The goal of modern General secondary education in the conditions of transition to the model of result-oriented education is to ensure the further development of students' abilities to cognition, creative use of the acquired knowledge in any educational and life situation, readiness for self-development and self-management throughout life, i.e. the formation of functional competence.

The results of the theoretical analysis of pedagogical research on the functional competence of students show that the issues of pedagogical research in the subjects of natural sciences are studied individually (Nurgiyantoro et al., 2020). In addition, the results showed that the best practice of teaching based on the formation of functional competencies is not generalized, there is no unified concept and technology for creating and developing an educational environment for the formation of functional competencies of students in the field of natural sciences, especially physics.

Currently, as shown in the works of N. Rybakina, O. Bakhlova, I. Bakhlov, I. Napalkova, A. Soldatova, A. Hakim the competence approach serves as the basis for updating the content of both general and professional education (Rybakina, 2018; Hakim, 2015). The concept of "competence" comes from the Latin competens, competentis, which means proper, capable. In the dictionary of modern Kazakh literary language, competence is defined as awareness in any field of knowledge – competent-knowledgeable, knowledgeable, knowledgeable (Instefjord, Munthe, 2017).

Despite the limited influence of the documents defining the use of relations between universities in accordance with common standards (Aleksić et al., 2022), there is an uneven degree of development of an important field of teaching natural sciences. Although the concepts of "competence" and "official activity" are currently formed, the unified system of its formation and the method of their formation have not been sufficiently studied. Despite a number of articles aimed at assessing the competence index of university students (Škrinjarić, 2022; Sarapaivanich et al., 2019; DeGrande et al., 2018) it is clear that our research problems are far from being solved.

Subjects related to the topics of "Physics" and the methodology of teaching physics at school, by themselves allow you to study the subject and teaching methods. Disciplines based on functional competencies are often poorly supported or not included in educational programs at all. Therefore, when laboratory classes and practical classes in physics are held, which are the professional skill of the teacher, we pay attention to the support and implementation of such work in the school, which attaches professional importance to teaching (Ramankulov et al., 2019; Lizunkov et al., 2020, Berdi et al., 2015).

Taking into account the place occupied by laboratory work and practical work on the subject of physics in terms of the formation of functional competence and literacy, we analyzed the scientific and methodological literature on the subject of physics.

Functional literacy training first appeared in the middle of the twentieth century in accordance with legislative requirements. Today, all over the world, the education system is devoted to key issues related to the elements of functional literacy, that is, affecting social, cultural, political and economic aspects, including the participation of people in lifelong learning. People can quickly interact with the external environment, develop as quickly as possible and work in a changing environment. In this regard, we agree with the good formulation of A.A. Leontiev: "many people are seen as executive directors who can use all the knowledge, skills and mental abilities of a new family to eliminate many homework assignments in other areas of human activity, communication and social interaction".

In the education system, the literature review on the competence approach made it possible to form the content of the basic concepts of "competence", knowledge about the basic definitions of the concept of "competence" (Chen et al., 2017). One of the definitions that formed the basis of our study is competence – the willingness or ability of students to apply the knowledge, skills and

methods acquired in professional activities to solve practical and theoretical problems (Arballo et al., 2019; Vázquez et al., 2019).

Thus, a functionally competent teacher is one who has special thinking and functional abilities, is ready to support students in their own cognitive activity and can direct their activities to introspection, can develop classes that support other areas of learning, teaches special strategies for active learning and can provide constructive feedback.

The selection of levels of formation of the functional competence of a teacher by different authors (Koliasa, 2021; Dimitrova, 2021, Shektibayev et al., 2019) is determined by the content of professional activity and the components of functional competence.

Functional competence implies compliance with the necessary pedagogical conditions and allows students to engage in productive, creative activities (Berestova et al., 2020; Yuan et al., 2017; Lin, Chuang, 2018). In order to achieve high performance of functional literacy of students, special pedagogical conditions must be created.

In articles on pedagogy and teaching methods, the concept of "pedagogical conditions" is often found (Gafiyatova et al., 2019; Bryakova et al., 2022, Dosymov et al., 2023). However, the generally accepted definition of this concept is not accepted by pedagogical science.

Researchers in the field of physics education (Furyaeva et al., 2017; Usembayeva et al., 2015) consider pedagogical conditions that increase the effectiveness of the future physics teacher. These studies state that pedagogical conditions "are objective and subjective prerequisites and requirements, the implementation of which will allow the teacher to achieve his goals in the educational process with the most optimal use of forces and resources."

Based on the conclusions of scientists, we conclude that, despite a fairly large number of studies devoted to the problem of implementing competence-based approaches in educational institutions, there are contradictions between the need for a physics teacher capable of solving new professional tasks and the underdevelopment of the system of preparation for their solution.

These prerequisites allowed us to formulate the problem and purpose of the study: determining and substantiating the component composition of functional competencies of students in physics, the formation of General and special functional competencies and internal motivation to a functional position in solving problems; determining and experimentally confirming the pedagogical conditions necessary for the implementation of the maximum success of functional literacy of students in the study of disciplines of the natural science cycle at the University; development and diagnostics of structural components of students ' readiness to solve functional problems in the study of physics.

The purpose of the study determined the setting of the main research tasks:

- analyze modern scientific approaches and requirements to the functional competence of students, clarify its concept and content for the discipline of physics;
- To identify the features of functional competence of students on the example of teaching physics;
- Determination of indicators and criteria of students' readiness for functional literacy in the study of physics;
- Experimental identification of positive/negative changes in the indicators of functional literacy of students as a result of the implementation of the developed pedagogical conditions.

Research hypothesis: the productivity of students ' functional literacy in the process of studying physics is provided if:

- The content and characteristics of the student's functional abilities are explained;
- Certain subjects of the natural science cycle (for example, physics) are defined and take into account the totality of educational conditions necessary for productive functional literacy of students;
- Determines indicators and criteria of readiness for students' academic performance in the study of subjects of the natural science cycle.

2. Materials and methods

Method of research

Scientific methods used to solve the tasks set during the study:

- theoretical: conducting comparative work on research work on a similar topic; To find out the degree of interest of the international academic community in functional competence, the scientific literature is analyzed using two main citation indexes used worldwide to measure

research results: Web of Science and Scopus. More than 50 papers on this topic were identified in both databases.

- empirical methods: direct and indirect pedagogical observation, testing, questionnaires, product analysis, expert evaluation, self-assessment, experimental work. These methods were aimed at identifying the degree of formation of the main components of readiness for functionality and identifying the optimal didactic conditions that stimulate the development of functional competencies. While investigating the components of functional competence that we identified, we used questionnaires that we developed to interview students.

- statistical: mathematical and statistical data processing; The student's t-criterion was obtained in order to determine the statistical significance of the difference in average values ($p = 0.01$). Identification of differences in quantitative indicators obtained based on the results of a pedagogical experiment, we used a nonparametric χ^2-criterion with a probability of an acceptable error of 0.01.

The research was conducted at the Khoja Akhmet Yassawi International Kazakh-Turkish University, M. Auyezov South Kazakhstan state University. A total of 86 students aged 18 to 20 years took part in the experiment (Table 1). The number of participants in the forming experiment is 86 people (including the control group – 42 students, the experimental group – 44 students).

Table 1. Detailed information about the student participating in the experiment

<table>
<tr><th>Group</th><th colspan="2">Number</th><th>Percentage (%)</th><th>Total</th></tr>
<tr><td>Experimental</td><td colspan="2">44</td><td>51 %</td><td rowspan="2">86 (100 %)</td></tr>
<tr><td>Control</td><td colspan="2">42</td><td>49 %</td></tr>
<tr><td rowspan="4">Gender</td><td colspan="2">female (51)</td><td rowspan="2">59 %</td><td rowspan="4">86 (100 %)</td></tr>
<tr><td>Control
24</td><td>Experimental
27</td></tr>
<tr><td colspan="2">male (35)</td><td rowspan="2">41 %</td></tr>
<tr><td>Control
18</td><td>Experimental
17</td></tr>
</table>

The research was carried out in three stages:

At stage 1, the research problem is substantiated and the scientific literature is analyzed, a generalizing work on pedagogical experience is carried out, in accordance with the hypothesis, the purpose of the study and the expected result are determined.

At the 2nd stage, a study of the current state of the formation of functional competence of students was conducted. Work has been carried out on the development of technology for the development of the educational environment for the productive functional competence of students in physics. The indicators of functional competence are determined, the factors and pedagogical conditions affecting its formation are determined. A pedagogical experiment was conducted.

At the 3rd stage, the structuring and refinement of the experimental data obtained was carried out, the processing and generalization of the research results were carried out, conclusions were formulated.

3. Results

A large amount of scientific material has been accumulated for the effective organization of work on the formation of functional competence of students at various levels of pedagogical education. The results of the literature analysis made it possible to determine the pedagogical conditions for the implementation of this task. Based on this, we have developed an algorithm for organizing the formation of functional competence of students:

- formation of interest in a specific scientific problem in the field of physics;
- creating conditions in the process of teaching physics in which the student wants to learn in a new direction and acquire some skills at the moment;

Analyzing the above studies, we believe that the results of functional literacy of students depend on many factors (Table 2).

Table 2. Factors of success of functional literacy of students

Factors of success of functional literacy of students	
Subjective	Individual characteristics of students
	The level of preparedness of the student
Objective	The conditions of the educational environment
	Organization
	Diagnostics and control of the student's functional literacy
	Information environment

In order to achieve high performance of students ' functional literacy, it is necessary to create special pedagogical conditions.

We consider the necessary pedagogical conditions for the formation of functional literacy of students in a complex: organizational; didactic; installation-target; logical-structural; diagnostic-effective (developed by T.V. Argusmanova) (Figure 1).

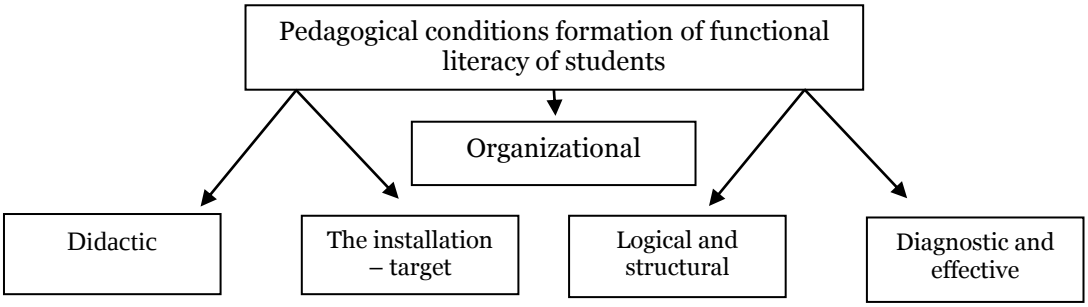

Fig. 1. Pedagogical conditions for the formation of functional literacy of students

- organizational: to determine the features of the formation of functional literacy in higher educational institutions, a general understanding of the functional competence of students in accordance with the disciplines of the Natural Science direction, the main criteria for selecting materials for their own research; to understand logical and structural, educational-didactic and effective teaching situations;
- setting and target: orientation of the goals and objectives of the educational process to the formation of functional literacy of students.
– the logical framework: ensuring cross-curricular links in the teaching of natural Sciences; development of educational technology, involving some stages in the formation of functional literacy in the study of physics; the implementation of subject-subject interaction between teacher and learner in the research process;
- didactic: Introduction of new teaching methods into the educational process; development of students ' functional literacy based on the use of a set of techniques.
- diagnostic and effective: primary diagnostics (identification of students ' motives to engage in research activities, learning goals); diagnostics levels of functional literacy in the process of studying natural science subjects in accordance with the developed criteria (Table 3).

In accordance with modern educational requirements, we note the need to develop the basic concept of functional literacy of students in each university and its relevance.

The proposed structure of student readiness developed by the authors assumes the necessary relationship and interdependence of all components and criteria indicators of components. The overall readiness for functional activity of students is determined by such levels as low, medium and high.

Table 3. Structural components and criteria indicators of functional competencies

Structural components	Criteria indicators
Motivational-Value	Motivation of teaching and cognitive activity, curiosity about physics; the desire to learn new things; independence in the process of teaching, decision-making and evaluation.
Emotionally-Strong-willed	Emotional (positive) attitude to study (inspiration) and research (creative impulse); ability to overcome cognitive difficulties.
Intellectually-Educational	The level of intelligence; the ability to cognitive reflection.
Practical	Ability to set problematic and search questions and problem problem; ability to put forward hypotheses; goal; determine the subject; ability to structure the material; skills to conduct an experiment; knowledge of methods of action in non-standard situations; ability to extract knowledge from reality; ability to state the course, results of work; ability to classify facts;

Thus, the organizational and pedagogical conditions identified by us for the formation of functional literacy of students in the process of studying natural Sciences allow us to proceed to the empirical study of the solution of the research problem.

Results of an experimental study

In our study, we applied a natural formative experiment conducted in the conditions of the educational process in a General education institution during the course of regular and extracurricular activities. The experiment required the necessary organization of the process based on the identified pedagogical conditions.

To test the hypothesis about the statistical significance of the difference in average values, the student's t-test was used at a one-percent confidence level (p=0.01). To identify the differences between quantitative indicators obtained as a result of a pedagogical experiment, we used a nonparametric χ^2-test with a 0.01 error probability. Tables 4–6 were used to visually represent experimental data.

Table 4. Dynamics of readiness for functional activity in students of the experimental group

Components of readiness for functional activity	Start of the experiment (in %)			End of the experiment (in %)		
	High level	Average level	low level	High level	Average level	low level
Motivational-value approach	13	64	23	40	60	0
Intellectual and cognitive	13	60	27	36	60	4
Emotional-strong-willed	9	68	23	36	60	4
Practical	13	55	32	45	55	0

Table 5. Dynamics of readiness for functional activity in students of the control group

Components of readiness for functional activity	Start of the experiment (in %)			End of the experiment (in %)		
	High level	Average level	High level	Average level	High level	Average level
Motivational-value approach	14	66	20	19	71	10
Intellectual and cognitive	14	57	29	19	61	20
Emotional-strong-willed	5	72	23	10	76	14
Practical	14	57	29	19	57	24

Table 6. Dynamics of readiness for functional activity in students of the control and experimental groups

Components of readiness for functional activity	Level	Before experiment (in %)		After experiment (in %)	
		TG	EG	TG	EG
Motivational-Value Approach	High	14	13	19	40
	Average	66	64	71	60
	Low	20	23	10	0
Intellectual and cognitive	High	14	13	19	36
	Average	57	60	61	60
	Low	29	27	20	4
Emotional-Strong-Willed	High	5	9	10	36
	Average	72	68	76	60
	Low	23	23	14	4
Practical	High	14	13	19	45
	Average	57	55	57	55
	Low	29	32	24	0

The empirical value of criterion χ^2 equal to 36.7 exceeds 0.01 with a permissible error probability of 13 %. Determination of levels by this motivational-value component of the distribution of students of control and experimental groups, statistical analysis with the help of Criterion χ^2 shows the importance of differences between the control and experimental group at the final stage. As well as a final study between the distributions of the experimental group in the initial and experimental group (χ^2empir. =77.59).

Consequently, as the results of statistical analysis showed, in the experimental group the number of students with a high level of motivation and value component increased by 21%.

In addition, our study based on empirical analysis showed that there are statistically significant differences in the performance of students in two groups, that is, in the control and experimental groups, according to the levels of the intellectual and cognitive component (χ^2empir. = 25.8, confidence of 0.01).

The presence of differences is also observed between the indicators of the experimental group in the initial and final observations according to the principle of significance (χ^2empiric = 55.77). Consequently, it is observed that the number of students who showed low results according to this component decreased by 16 % at the end of the experiment and a high level by 26 % is convincing.

4. Discussion

The lack of a diagnostic method by which it is possible to assess the level of formation of the studied competence creates difficulties in the full implementation of the formation of functional competence. Diagnostics will be aimed at identifying strengths and weaknesses, potential abilities and needs in the professional activities of the teacher. In addition, it allows you to identify difficulties in the implementation of the educational process and solve it.

The method of diagnosing the level of formation of functional competence requires a scientific basis and clear Organization, an open procedure (Guduru, Bommanaboina, 2021).

These results are in line with the research results of Quitadmo and Kurtz (2007) and Fuad et al. (2017) reporting that the application of different learning models had a higher effect size on the achievement of students' key competencies skills than that of the students taught by using the conventional learning (Quitadmo, Kurtz, 2007; Fuad et al., 2017). The research by Tran, Dat Tran, (2013) showed that the integration of learning models was proven to be effective in improving students' skills, on the other hand, the conventional learning is proven not to empower students' skills (Tran, Dat Tran, 2013).

The considered examples show the complexity and ambiguity of determining the level of formation of qualifications. Despite the difference in the calculation of quantitative characteristics indicating the level of qualification formation, most methods mainly use tests, questionnaires and expert assessments. The analysis shows that not every researcher can use this method due to the

complexity of the procedure for conducting and calculating the competencies under study, due to the narrow direction, which is the formation of competencies in certain academic disciplines, therefore, work continues to create a relatively simple method for establishing the level of formation of professional competencies.

This study is limited to the problems of the formation of functional competencies of students on the example of physics. The factors and pedagogical conditions influencing the formation of the identified functional competence are recommended to be used in all disciplines in the specialty physics, and this will allow to achieve good research results in the future.

5. Conclusion

The program developed and tested by us for the development of indicators of functional competence and organization of functional activities of students:

- improving the factors that influence the formation of functional competence: the ability to understand intentions, methods and actions to perform tasks based on functional competence; the ability to understand and express thoughts that require action; the ability to be creative or creative; the ability to overcome cognitive difficulties; a positive attitude towards planning work; the ability to sort out physics knowledge; the ability to be independent; the ability to conduct research taking into.

- development of a positive attitude to functional activity in the field of physics, the student's motivation to engage in research activities, skills in applying scientific methods in research and progress in a number of physics disciplines. The analysis of the obtained data on the results of the program implementation shows a stable dynamics of the level of development of educational, cognitive and creative research criteria indicators.

So, the results of the study will serve as an excellent scientific document for subsequent research in the field of functional competence, and will also have a huge impact on the development of science and technology, if viewed from the side of professional activity.

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