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Original Article

Foundations of reflexive system of professional education using innovative information and communication technologies

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ABSTRACT

This study focuses on the development and implementation of a reflexive system for professional education aimed at future chemistry teachers, integrating innovative information and communication technologies (ICT). The current pedagogical landscape in Kazakhstan emphasizes the need for adaptable, responsible, and independent teachers capable of applying non-traditional methods and meeting national education standards. The proposed reflexive system combines reflexive learning, independent student work, and ICT-based educational environments to enhance professional competencies. An experimental study was conducted with undergraduate, master's, and doctoral chemistry students across several universities, comparing traditional training methods with the proposed system. Results demonstrate significant improvements in students' methodological knowledge, self-regulation, critical thinking, and reflective skills. The system facilitates goal-setting, planning, diagnostics, and monitoring of teaching activities, fostering professional self-determination. Findings suggest that the integration of reflexive learning and ICT not only increases the effectiveness of professional education but also develops students' creativity and pedagogical independence. This approach provides a scalable and innovative model for enhancing the quality of chemistry teacher training within multi-level higher education systems.

Keywords: Reflexive learning, Professional education, Chemistry teachers, Undergraduate students, Innovative ICT, Pedagogical competence

Introduction

The relevance of the study is determined by the fact that the evolving Kazakh society requires an updated system of multi-level higher pedagogical education that meets the demands of the modern era [1, 2]. In the 21st century, perceptions of the meanings and goals of higher education, as well as its content and organization, are changing [3-7].

The implementation of a learner-centered educational paradigm under these new conditions presupposes that educational activities should enable and support innovations aimed at enhancing the student's role as a subject in designing their individual educational trajectory [8, 9]. Innovations help overcome the traditional alienation of students and their personal educational meanings from formal knowledge and externally imposed components of the educational process [10-12].

Currently, new requirements are being put forward for the professional and pedagogical training of future chemistry teachers [13-15]. These include readiness for change, the use of

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non-standard methods and forms of teaching, as well as responsibility and independence in decision-making [16-18].

Therefore, at the present stage, the goal of professional chemistry education at universities is to improve the quality of methodological training by aligning the content and organization of the educational process with national requirements, through the formation of methodological competence in chemistry teacher trainees [19, 20].

However, the results of our study indicate that bachelor training programs at Kazakhstani universities are still dominated by approaches that result in formal knowledge acquisition in the process of learning chemistry teaching methods [21-23]. Among the problems identified are insufficient use of information and communication technologies (ICT), low motivation levels, a lack of attention to developing students' creative activity, critical thinking, pedagogical reflection, and deficiencies in the methodological support of the educational process.

In the context of today's information society, it is evident that there is a need to improve the professional education of future chemistry teachers by incorporating ICT tools [24-26]. To meet modern standards, there is an urgent need to develop a concept for innovative professional education for future chemistry teachers, as well as a subject-specific ICT-based environment for teaching chemistry methodology.

The ideas of informatization and the formation of reflection hold methodological significance for the professional education of future chemistry teachers at universities. Chemistry students must perceive the university's information-educational environment as a means of enriching their personal qualities and fostering reflection. This enables them to amplify both the potential of the educational environment and their own creative intellectual capacity, which is crucial for mastering innovative learning and, subsequently, their professional teaching activities [27-29].

A particularly important component of bachelor-level chemistry teacher education for work in modern Kazakhstani schools is the organization of reflexive learning, which helps activate mechanisms of professional self-determination and self-development. The value of reflection in learning chemistry teaching methods lies in its action-oriented, socially and personally directed nature.

Through reflexive learning, bachelor-level chemistry students learn to perform various professional tasks, regulate their processes, and master the knowledge and mechanisms necessary for such regulation. In innovative professional education, reflection engages students in goal-setting and planning, applying plans in practice, conducting diagnostics, and monitoring processes, conditions, and outcomes of their activities. Reflection in the context of innovative educational processes in chemistry methodology plays an educational role, contributing to the development of professional competence in future chemistry teachers [30-32].

The above confirms that the current issues in training chemistry bachelor students within the multi-level system of higher pedagogical education are largely due to the insufficient development of the theoretical and methodological foundations of an innovative professional education system based on self-regulation and reflection. There is a need to strengthen the reflexive component of the chemistry teaching methodology, and to increase opportunities for professional and personal self-expression and self-realization in accordance with the essence of the chemistry teaching profession.

Therefore, in our study, reflection became the foundation for developing a reflexive system of professional education for chemistry bachelor students, making use of the resources of the university's information-educational environment.

The goal of the study is to improve the quality of professional education for chemistry bachelor students through the use of a reflexive professional education system that incorporates information and communication technologies (ICT).

Research tasks

1. To design a reflexive professional education system for chemistry bachelor students using ICT.
2. To create, based on the developed concept, an information-educational environment for the professional education of future chemistry teachers, and apply it to develop professional competencies in a blended format (combining in-person and distance learning).
3. To experimentally test the effectiveness of the reflexive professional education system for future chemistry teachers using ICT in the context of a multi-level system of higher pedagogical education.

Materials and Methods

In the course of the study aimed at developing and testing the effectiveness of a reflexive system of professional education for future chemistry teachers using information and communication technologies (ICT), a comprehensive approach was implemented. This approach included theoretical, empirical, and experimental methods.

The research was conducted over a period of three years within the framework of the multi-level system of higher pedagogical education in the Republic of Kazakhstan. The primary experimental base was Abai Kazakh National Pedagogical University (Almaty), with additional scientific and methodological support provided by faculty and students from Dostoevsky Omsk State University (Russia).

Participants in the study included undergraduate students majoring in Chemistry, as well as master's and doctoral students enrolled in pedagogical programs. Several study groups were formed: two experimental groups (EG-1 and EG-2), in which the developed reflexive system was implemented, and a control group where training followed the traditional format. Each group consisted of 25 participants.

The experimental work was organized in stages:

Stating (diagnostic) stage

At this stage, the initial level of students' professional and methodological competence was assessed. Methods included testing, questionnaires, self-assessment, and expert evaluations by instructors. Additionally, academic documentation and students' learning products were analyzed, along with observation of their behavior in educational situations. The data collected formed the basis for designing the formative stage.

Formative stage

During this stage, the authors' reflexive system was applied in student training. It included:

The use of electronic educational resources (EER),

Application of the Moodle distance learning platform,

Integration of immersive technologies (augmented and virtual reality),

Active use of case-based learning, web quests, projects, and portfolio work,

Organization of blended learning formats, combining classroom sessions (lectures, seminars, lab work) with remote formats (forums, chats, video conferences),

Development of self-analysis, self-regulation, and reflective skills.

Students in the experimental groups studied within an integrative educational environment, which supported both individual and group learning, made extensive use of interactive methods, and allowed for personalized learning paths. Throughout the learning process, students were gradually involved in the planning, diagnosis, assessment, and reflection on their pedagogical activities.

Control stage

At the final stage of the experiment, data were collected again to assess the changes that occurred during the training. The same diagnostic tools were used as at the diagnostic stage: repeated testing, surveys, expert evaluation, and self-assessment. Additionally, computerized testing and monitoring of methodological competence formation were conducted in the following areas: reflective, epistemological, design, instructional, diagnostic, research, and educational.

To ensure the experiment's proper course and reliable results, four groups of indicators were identified in the structure of the research activity. Each group reflected different aspects of participant engagement, providing clear insights into the effectiveness of the reflexive professional education system for future chemistry teachers within the university's information-educational environment:

The first group the leading one included indicators based on the personal characteristics of chemistry students.

The second group included additional indicators reflecting the professional skills and pedagogical tact of the instructors.

The third group comprised factors influencing the learning process, particularly components of the social environment.

The fourth group consisted of factors related to result control.

Computer-based testing and online questionnaires were used during the experimental work.

To assess the effectiveness of the reflexive learning system using the innovative educational-methodological complex, a criteria-based assessment framework was developed. It included criteria for effectiveness, development, process orientation, and reflexivity, along with their corresponding indicators. Professional education for future chemistry teachers assumes a logic of progression in mastering the subject and self-regulation of this process. To detect progress in professional competence at the strategic, tactical, and operational levels of regulating pedagogical activity, monitoring was carried out using the developed indicators.

The indicators for assessing the formation of professional competence in chemistry teachers are presented in **Table 1**.

Table 1. Qualitative Characteristics of Professional Competence of a Chemistry Teacher

Level of Regulation of Pedagogical	Indicators of the Formation of Professional Competence in Chemistry Teachers
Strategic	Knowledge and ability to use technical tools and ICTin a rational combination with traditional means of teaching chemistry Ability to develop and apply electronic didactic and educational software tools in chemistry education Ability to design a system of teaching aids for chemistry based on the integrated use of instructional tools Ability to develop working curricula and elective course programs Ability to apply teaching methods and technologies in chemistry education, including ICT
Tactical	Knowledge of new pedagogical technologies and their implementation specifics in chemistry education Understanding of general methods for designing objectives, content, methods, and forms of the educational process in the context of improving chemistry education Ability to create an automated workplace for a chemistry teacher Knowledge of the specifics of methodological-chemical activities when using ICTtools in combination with traditional means Ability to design chemistry lessons and other instructional formats Ability to set predictive goals and objectives for chemistry lessons Ability to use chemistry teaching aids in an integrated way
Operational	Ability to select teaching methods for chemistry according to the content of the learning material Ability to choose organizational forms of chemistry instruction based on the content Knowledge of the main directions of value-oriented chemistry teaching Knowledge of the ideas and methods of developmental chemistry education

Understanding the capabilities of the information-subject educational environment for chemistry instruction
Ability to select chemistry teaching tools based on content and contextual conditions

To demonstrate the effectiveness of the developed reflexive learning system for bachelor's, master's, and doctoral students in the methodology of teaching chemistry, the questionnaire identified seven types of methodological competencies of a chemistry teacher: reflexive, gnoseological, design-oriented, instructional, diagnostic, research, and educational.

Analysis and processing of results

For comparison, a survey was conducted among student groups who studied without using the reflexive system of professional education with the application of ICT. In the statistical processing of results, to test the homogeneity of two independent small samples (each with no more than 25 participants), the Wilcoxon test was used. It applies to random variables with unknown distributions. If the samples are homogeneous, they are considered to be drawn from the same general population and have the same distribution, which in our case would indicate the absence of a pedagogical effect from using the reflexive professional education system for chemistry bachelor students with the application of ICT.

The statistical hypothesis of sample homogeneity was tested at a significance level of 0.95. To test the hypothesis of equality of the general mean values of the parameter, the Student's t-test was applied. Group comparisons (each with each) were conducted based on the above-mentioned methodological competencies.

Results and Discussion

The developed reflexive system of professional education using ICT consists of a set of five interrelated components: the goal-setting, content, operational-activity, regulatory, and reflective components **(Figure 1)**.

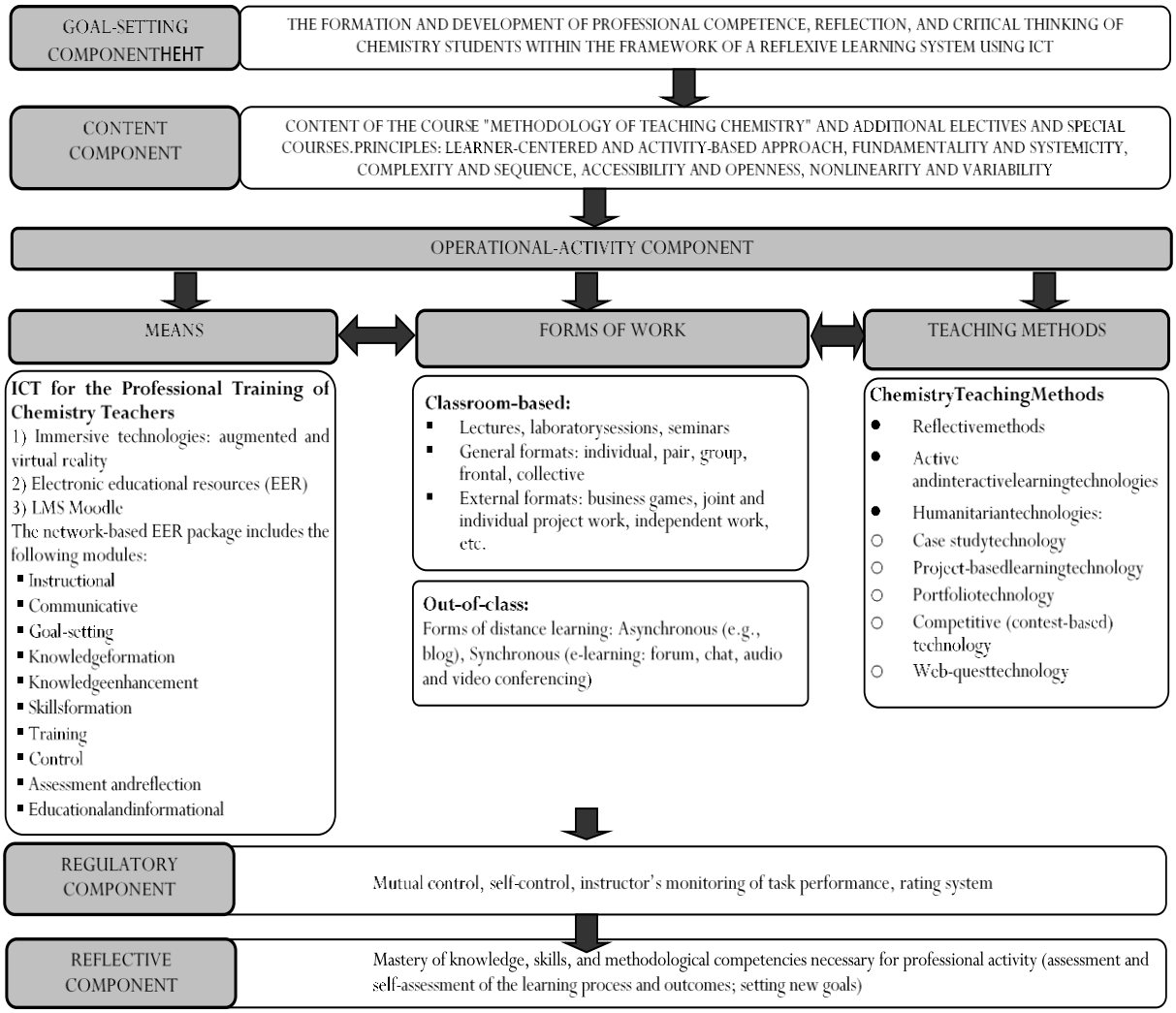


Figure 1. Structure of the Reflexive System of Professional Education for Future Chemistry Teachers in the Republic of Kazakhstan

*A*ccording to the research results, the most significant "leap" in indicators occurred at the operational level. This demonstrates the effectiveness of training based on the developed reflexive system of professional education using ICT.

The dynamics of students' professional competencies during the experiment at the strategic, tactical, and operational levels of pedagogical activity regulation are presented in **Figure 2**.

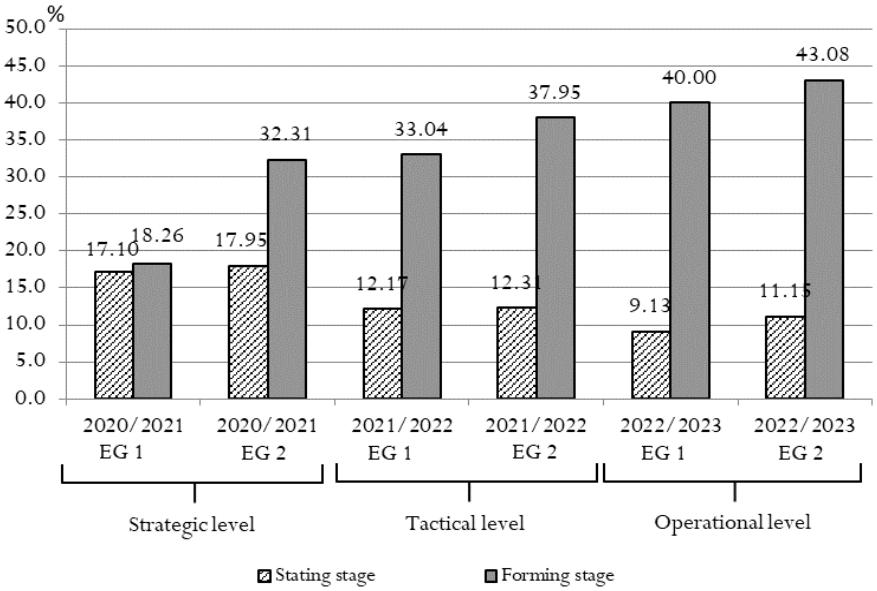


Figure 2. Dynamics of Students' Professional Competencies During the Experiment (EG 1 – Experimental Group 1; EG 2 – Experimental Group 2)

According to statistical analysis, students in groups 0 and 3 who were trained using the proposed reflexive learning system demonstrated better methodological preparation. This indicates that the reflexive education system using ICT is more effective. The results of the experiment confirmed the research thesis that the application of the developed reflexive system of professional education for future chemistry teachers using ICT enables the development of all components of their professional competence.

In the 1st group of indicators, variables related to the personal level of organization were identified: successful assimilation of methodological-chemical knowledge, creative potential, students' ability for self-development, information culture, and motivation for professional activity. From **Figure 3**, it is evident that the knowledge retention coefficient among students increased according to the results of the final assessment.

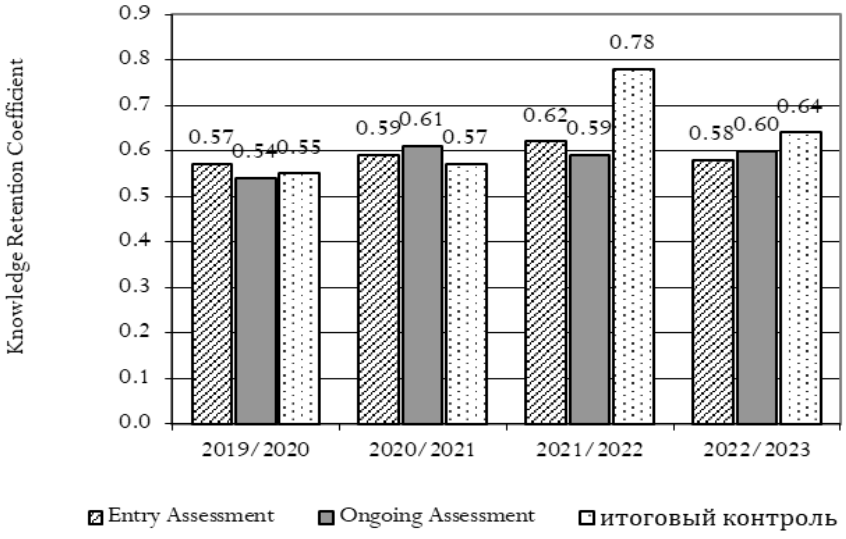


Figure 3. Dynamics of the Knowledge Retention Coefficient Among Students

In the analysis of the obtained results comparing students' success in knowledge acquisition in the methodology of teaching chemistry, standard deviation and coefficient of variation were used. Statistical indicators of knowledge retention consistently decreased as students advanced through methodological disciplines.

This "leveling" of knowledge retention across groups may indicate the universality of the implemented reflexive system of professional education using ICT for all categories of students. This can be explained by the wide array of modern ICT tools, the ability to choose an individual educational trajectory, and the self-regulation of learning activities by chemistry bachelor students.

Over the course of three years of experimental work, a positive dynamic was observed — an increase in the number of students with high and medium levels in the first group of indicators, which are associated with students' personal characteristics. These changes occurred during the formative stage of the experiment **(Figures 4 and 5)**.

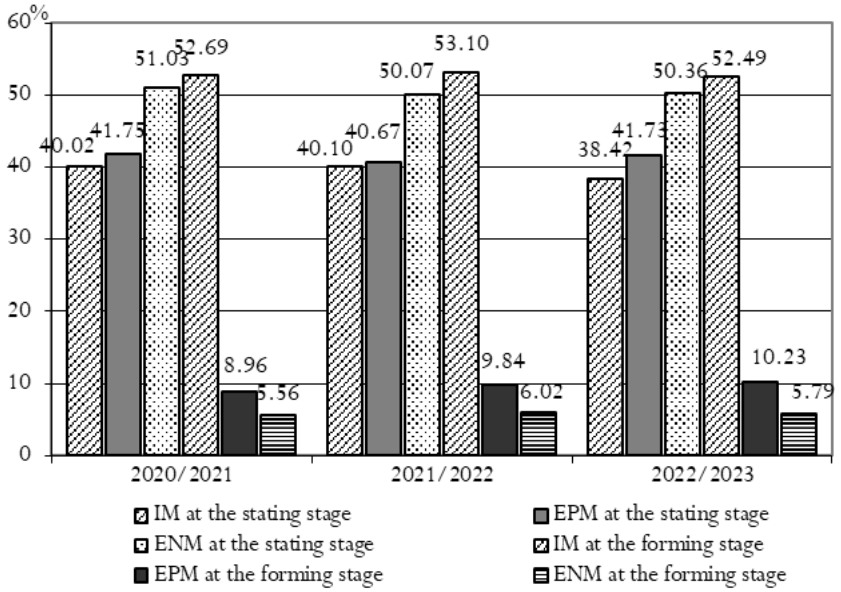
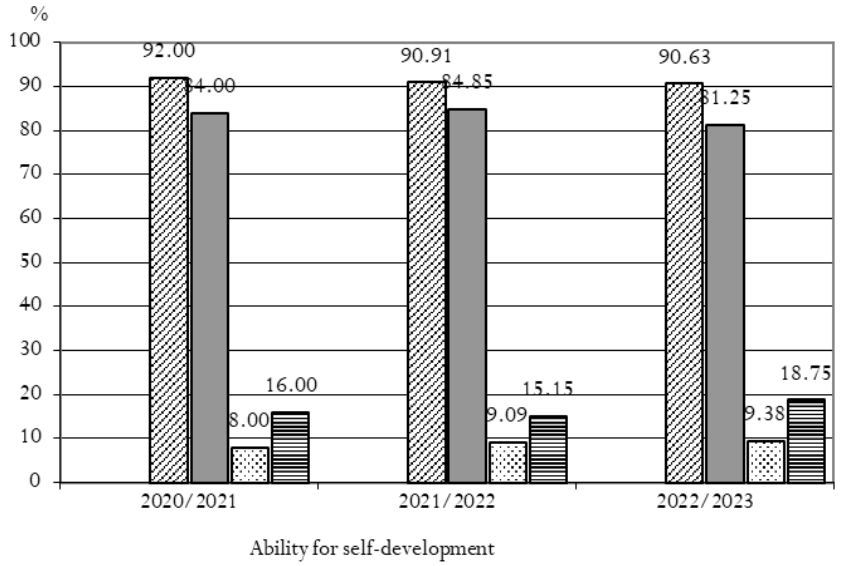
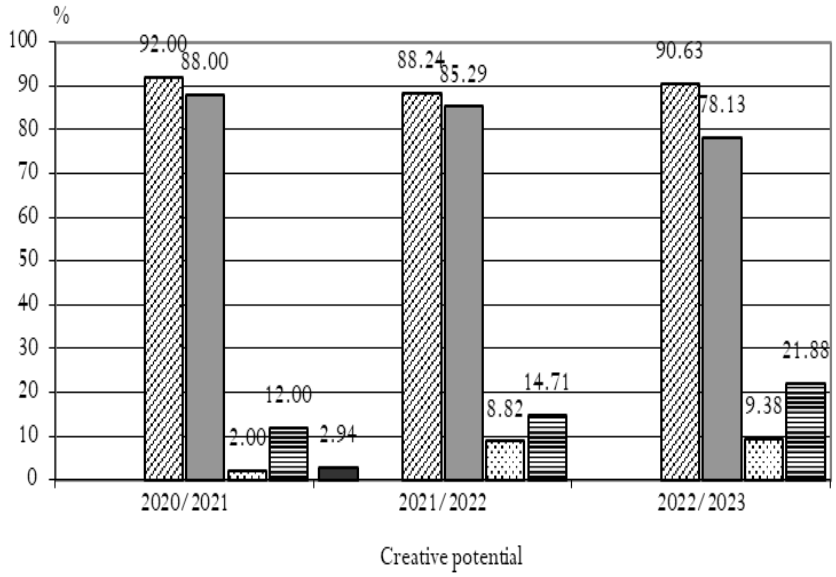


Figure 4. Dynamics of Motivation for Professional Activity During the Experiment (IM – internal motives; EPM – external positive motives; ENM – external negative motives)



a)



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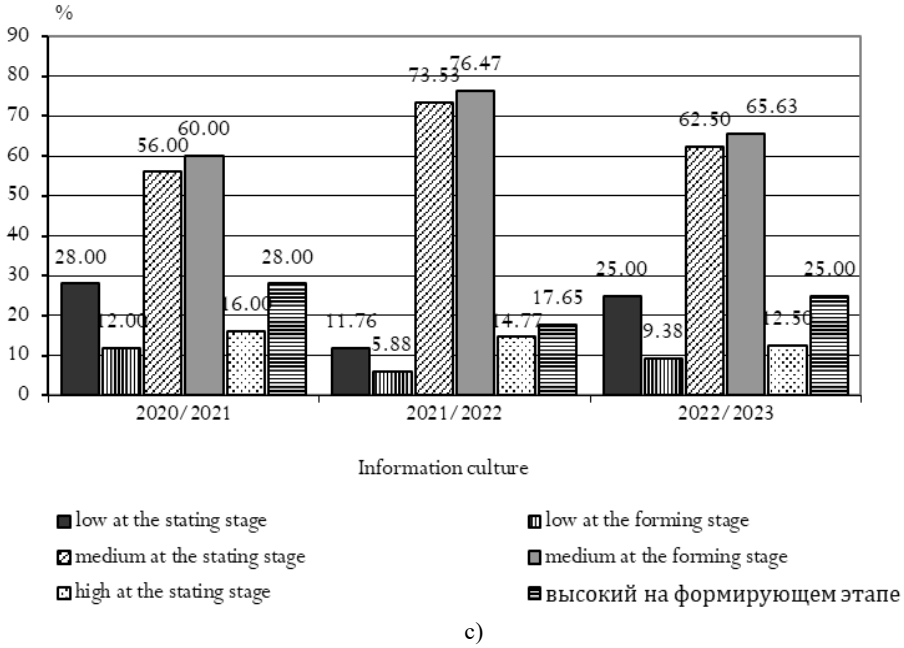

c)

Figure 5. Dynamics of Indicators Determined by the Personal Characteristics of Chemistry Bachelor Students During the Experiment

Conclusion

1. The concept of a reflexive system of professional education for chemistry bachelor students has been substantiated and implemented. It is based on the theory of reflexive learning and the logic of students' mastery of methodological disciplines. The concept includes foundational ideas, goals, objectives, patterns, principles, and content. The patterns form the conceptual core and reflect the specific nature of students' engagement with the cycle of methodological disciplines.
2. A reflexive system of professional education for chemistry bachelor students has been developed using innovative ICT.
3. In the course of experimental work, the quality and pedagogical effectiveness of innovative ICT in chemistry teacher education were identified. The positive impact of the reflexive system of professional education using modern ICT and an information-educational environment (IEE) on the effectiveness and quality of professional training was confirmed.

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Conflict of interest: None

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Ethics statement: None

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