Ministry of Education and Research of the Republic of Moldova

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# FORMATION OF THE CHEMISTRY RESEARCH COMPETENCE IN THE INTERDISCIPLINARY UNIVERSITY CONTEXT

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## SUMMARY

# ABBREVIATION LIST

| | | |
|---|---|---|
| Å | - | angstrom |
| RC | - | research competence |
| PC | - | professional competence |
| NQFRM | - | National Qualifications Framework in the Republic of Moldova |
| DFT | - | Density Functional Theory |
| DMF | - | N, N'-dimethylformamide |
| DMSO | - | N, N'-dimethyl sulfoxide |
| IR | - | infrared |
| FTE | - | full-time education |
| PTE | - | part-time education |
| Nia | - | nicotinamide |
| i-Nia | - | iso-nicotinamide |
| $NioxH_2$ | - | 1,2-cyclohexanedione dioxime |
| $paoH_2$ | - | pyridine-2-aldoxime |
| RM | - | Republic of Moldova |
| RMN | - | nuclear magnetic resonance |
| S-Nia | - | thionicotinamide |
| ICT | - | Information and Communication Technologies |
| TSU | - | Tiraspol State University |

# INTRODUCTION

The trends in the development of contemporary education provoke scientific debates in the university pedagogical community regarding the research culture, with sustainable applications in self-regulation of the quality of research training in an interdisciplinary context. Education Code of the Republic of Moldova No. 152 of 17.07.2014 stipulates that "in the institutions offering higher education programs, the research, development and innovation activity is carried out to produce knowledge and professional training of highly qualified specialists". The current stake of postmodern civilization is the research training of social activism, the development of professional skills based on research training and the realization of scientific research that will strengthen the economy, ensuring social welfare. However, the mission of production, transmission of the new knowledge and values of science, of formation, necessary for future generations, remains, at the expense of higher education institutions, as educational centers, models of scientific education for future generations. The analysis of the historical retrospective of the future of humanity in contemporary society depends, without a doubt, on the proper capitalization of the pedagogical opportunities of university professional training. In this connection, *the research culture* ensures the integrity of the formation of the investigative style and the dynamics of the optimal capitalization of the investigative potential of the students in a socio-educational context.

The deep philosophical reflections of policymakers on the psychological complexity of university education based on competences, supporting the processes of innovation culture formation, are the cause of the current higher education orientation toward prioritizing the formation of research competence. Research competence, a reference system in terms of the study programs' aims, is a challenging concept of postmodern professional pedagogy. There are many ways to define research competence, as well as many different definitions of this term that convey its importance in both the professional development of students and their personal growth. The list of operational definitions for the phrase research competence and their interpretive analysis provide scientific clarifications on the standards for teaching chemistry on the competence-centered curriculum. Although contradictory to a first analysis, the definitions advanced in the pedagogical literature, present elements of convergence of opinions, represented by the fact that the classical structure of competence aims at the integrity of knowledge, capacities, and attitudes, with its structural elements having an open and flexible character, depending on the current and prospective requirements of the society. This shows that, in all scientific areas, there is no consensus and a single definition of research competence, its optimal approach being of a constructivist nature. The meanings of the research competence depend on the contextual use of the term and the purpose for which the definition is formulated, for example, the purpose of developing a curriculum or training program focused on competences, defining new professional roles, or evaluating the effectiveness of professional competences.

The analysis of misunderstandings about the meanings attributed to research competence reveals that the knowledge, capacities, attitudes, and values necessary for students for social integration and professional success can be fully developed through the inter- and transdisciplinary approach in scientific research that presents an alternative training of functional professional competences and ensures the continuity of the lifelong training process.

The paradigm of implementing competences in didactics of chemistry involves their use as purposes of research training. The issue of addressing research competence and demonstrating the predominant transdisciplinary nature remain on the agenda of the scientific community worldwide. Dealing with the demands and challenges of the contemporary world means having the ability to make quick and efficient transfers between various curricular areas, to collect, synthesize and implement the knowledge, skills, abilities, and capacities acquired by studying various disciplines. At the same time, it is important to ensure the efficient and rapid transfer of new scientific knowledge and innovative technologies in the finalities and contents of university disciplines in order to increase the level of competitiveness of future specialists.

The global scientific community continues to prioritize focusing on research competence and demonstrating the predominance of transdisciplinarity. The capacity to quickly and effectively shift between different subject areas, collect, synthesize, and apply the knowledge, skills, and ability acquired by studying numerous disciplines, is necessary for meeting the demands and challenges of the modern world. In order to boost the degree of competitiveness of future experts, it is important to ensure the effective and faster integration of new scientific knowledge and innovative technologies into the aims and contents of university disciplines.

Contemporary teaching methodology is influenced by the evolution of scientific knowledge, new technologies, trends in society and the labor market. Higher education must adjust its policy documents and strategies to train competent specialists who could manage a variety of challenges and are ready to put scientific innovations into practice in a different fields. This is necessary because the dynamics and complexity of current socio-economic processes demand a constant adaptability of specialists to new realities in the professional field.

*The research competence has become the key concept of educational policies* at university level, having a strategic and decisive significance in the training of highly qualified specialists for the labor market. According to this viewpoint, research activities are a significant part of the university teaching process. In order to develop investigative and self-training competences, individual and autonomous work will be done, mainly through research projects and the elaboration of the bachelor's thesis, according to the methodology of implementing professional standards in higher education. The qualification level involves the coordination of team research activities, and openness to communication, implementation of innovative ideas. It is recommended that during the training, team research activities be designed.

Globally, the impact of training through research in the initial vocational training process with the potential for employment in related fields is highlighted in the training of qualified specialists. In this context, the methodology for training chemistry students' research competence involves the interdisciplinary correlation of the contents of the disciplines of chemistry, biology, physics, etc. The interdisciplinary approach is the relevant level of integration for the formation of chemists' professional competences. A number of complex real-world problems related to student training, development, and professional education can be solved by capitalizing on the principle of interdisciplinarity. The issue of professional competences formation in an interdisciplinary context is still relevant and well-timed. The studies at the faculty represent a period when knowledge from various fields can be integrated, and the most efficient way is participation in research projects. The interrelationship of Chemistry discipline contents with biology, physics, mathematics, geography, and informatics is based in the educational process on the training of students in the competences required for future specialists' efficient integration in various social situations. The knowledge gained will be more valuable if it is combined with specific competences in various application situations. The process of teaching-learning-evaluating chemistry is complex, with the goal of developing research competence in (chemistry, biology, etc.) students. The inter- and transdisciplinary approach of the study contents creates a favorable and necessary environment for the development of chemistry students' research competence, making it an educational priority.

The phenomenon of university innovation is dynamic, multifactorial, and multifunctional, which is why the valorization of innovation policies in higher education determines the conjugation of the university community's efforts to strengthen intellectual, research, and technological transfer potential through: scientific product innovations, process innovations, organizational innovations, and educational marketing innovations, among others, with the goal of ensuring the sustainability of higher education. The epistemic and deontological authority of university teaching staff is built on the quality of educational services provided by integrating research findings into university teaching, knowledge transfer, and significant innovation activity for the professional training of specialists in the knowledge society.

According to Article 9 "Innovative educational concepts: creativity and critical ideas" of the Universal Declaration on University Education, "in a changing world, there is a perceived need for a new vision and paradigm of higher education, which must be oriented towards research training of students". For these reasons, higher education institutions must train students to think critically, analyze societal issues, seek solutions, apply them, and assume social responsibilities. To achieve these goals, it may be necessary to rework the curriculum by employing new and appropriate methods, in order to avoid limiting oneself solely to the cognitive acquisition of disciplines. New teaching approaches will be promoted in order to facilitate the acquisition of critical, creative, and innovative analysis skills, as well as independent reflection and teamwork in multicultural contexts, where creativity involves combining traditional or local knowledge with scientific and advanced technological know-how. In order to develop students' research and innovation competences, academic staff must take on significant responsibility for the creative renewal of the curriculum.

Students' research activity, from this perspective, ensures the integrity and diversity of professional training, develops creativity, cooperation through research, develops attention by increasing motivation to strengthen and critically evaluate the degree of professional competences' training, and promotes career advancement. The scientific knowledge gained through research activity has a significant impact on the development of students' innovative thinking and investigative style. Chemistry students' professional identities are strengthened through participation in relevant planning efforts of student team research projects, in collaboration with university teachers from whom they will learn managerial strategies for managing scientific knowledge. The university environment organized in the spirit of the current paradigm of research culture will become fertile in terms of producing new scientific knowledge required for the professional placing of specialists.

The paper is recommended for first, second and third cycle students, as well as for teachers and specialists in the field of interest.

# CHAPTER 1. THEORETICAL AND CONCEPTUAL FRAMEWORK FOR THE DEVELOPMENT OF CHEMISTRY RESEARCH COMPETENCE

The content of this chapter includes the specific details of developing research competence through the study program in Chemistry, as well as the development of a system of theoretical ideas that present the viewpoints of authors in the field of general pedagogy and didactics of chemistry on the scientific significance of research competence in the context of policies. Promotion of a research culture through education. The relevance and significance of inter- and transdisciplinary approaches in chemistry research training results in the formation of students' innovative thinking, which includes research trends, professional development and innovative approaches to professional roles, research design initiatives, and creative transformation of the professional environment. It is opportune to develop *research and entrepreneurial competences* in the context of university vocational training for the field of *Natural sciences*, which offers additional professional values to young specialists who will contribute to the scientific and economic uplift of the community through professional creativity and innovative thinking.

## 1.1. SCIENTIFIC SIGNIFICANCE OF RESEARCH COMPETENCE

Contemporary pedagogy is a disciplinary or transversal pedagogy that develops complementary, theoretically and operationally-creative competences, generating good practices identified in the experience of various professions while being targeted in education projects for the twenty-first century, third millennium [1]. Competency-based education involves interactive and flexible teaching strategies that are tailored to students' needs and designed to encourage them to ask questions, solve problems by asserting themselves through critical thinking, which is expressed through initiatives, productive reflections, and motivation for research, development, and innovation. For these reasons, the assertion of research culture entails innovative thinking, which refers to the investigative competences required by specialists in order to compete in the labor market. The pedagogical mission of modern universities is to create a supportive university environment for the development of research culture in students. It has been discovered that contemporary students evoke a nonconformist mentality, one that is exploratory of new visions, with obvious tendencies to solve the problems inherent in modernizing teaching by discovering new knowledge specific to the field of experimentation of specific methodologies of scientific knowledge.

University teachers will formulate objectives aimed at knowledge, capacities, and attitudes that lead to the development of investigative competences and innovative thinking in this order of ideas. By encouraging new ideas and their implementation in professional internships, innovative university activities in general will have a complex structure and a pronounced scientific character. University teaching technologies will be oriented toward production, promotion of innovation implementation models, and rigorously planned in order to assert students' research competence as an integral result of the research processes in the unity of its dimensions, engaged at the organizational level.

In the context of higher education modernization, research facilitates the activation of students' autonomous learning, particularly for pedagogical theory and practice, as well as the development of research competences. According to this viewpoint, one of the directions for the evolution of higher education is to train students in the competence of searching for and using information through independent research. This objective requires the use of metacognitive strategies to reinforce students' need for knowledge. In this order of ideas, the university professional training process oriented toward the development of research competence of chemistry students can be interpreted as a form of creative team cooperation of university teachers and students in order to enhance their investigative potential to know transformations, reactions, processes and chemical phenomena.

Students will benefit from the creative and innovative thinking models of university students, creators of scientific information, essentialized, logically and coherently ordered, in accordance with the curricular requirements of the study programs, in university training activities. In this sense, the normativity of postmodern didactics (university didactics principles) involves specific methodological actions to promote motivation for research – a continuous learning process aimed at phased consolidation of research competences, which teachers must consider to ensure professional success.

The historical path to competence-based teaching implies their interpretation on the following key dimensions: 1) the evolution of the scientific meanings of professional roles and competences; 2) priorities resulting from the key competences formulated at European level and 3) the operationalization of general and specific competences in the university curriculum. At the theoretical and psychological levels of learning, we highlight the integrated character and succession of training events that lead to their development in the analysis of the competences formation process. In this case, learning has a strong inductive component (starting from well-defined elementary competences, to competences with a higher generality). It is primarily deductive, beginning with key European competences and progressing to training process competences. The main element is the transversal character and the orientation towards lifelong learning.

Throughout the history of university pedagogy, various interpretations and approaches to the scientific essence of investigative competence have emerged, determined by the specific complexity of the research activity and socio-professional expectations. This evolution manifested itself in the development of multiple interpretive models, which led to the clarification of the scientific identity of the term research competence. In the context of approaching the vocational training process through this perspective, it is important to first identify the importance of paradigm shifts in higher, classical, and current education, and then to analyze the other elements of the university teaching process that have formative effects on the efficiency of teaching professionalization. In order to achieve this, analyses of the development of professional competences as well as student growth for research and innovation in a professional setting become important.

The third area is limited to the application of curriculum competences in concrete learning situations and the design of the training process with the goal of developing research competences and obtaining university performances (Figure 1.1).

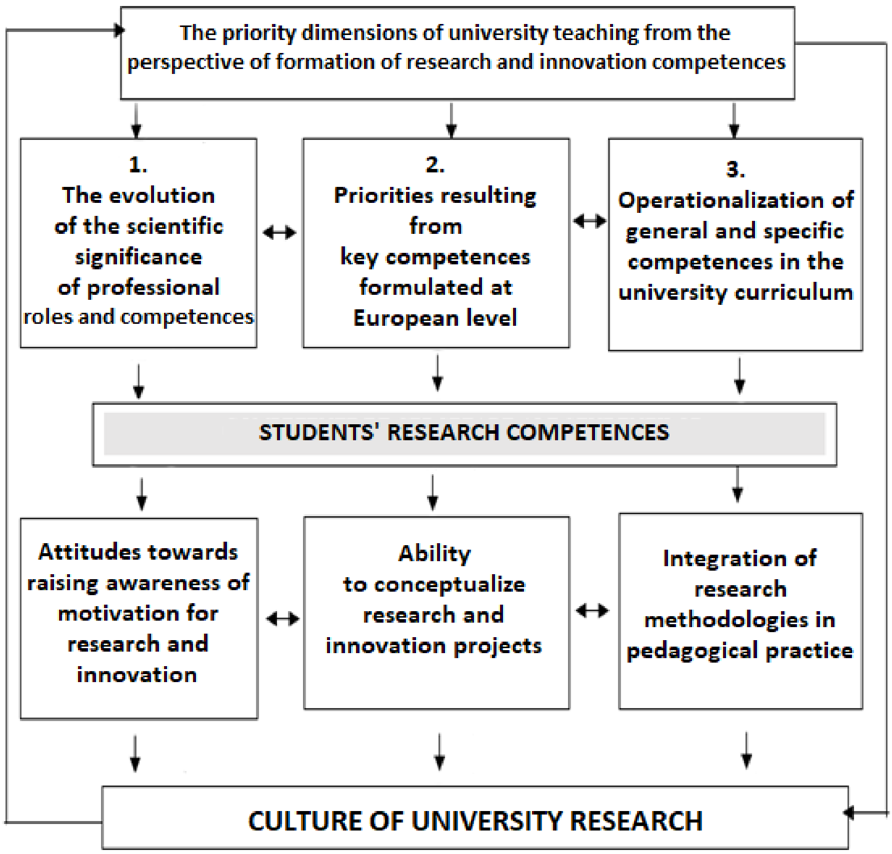


Figure 1.1. The priorities of university didactics from the perspective of formation of research and innovation competences

The evolution of scientific meanings of professional roles and competences is initially reflected in the meanings attributed to the term *competence*, defined as a structured set of articulated knowledge, capacities, and attitudes that allow people to solve problems in a professional field in a short period of time recognized as good.

The scientific content of the competence shows the interdependence of operational and instrumental competence, the manifestation of an interest in a field of knowledge, and the desire to conduct research. Competence in pedagogical terms refers to students' capacity to mobilize a wide range of knowledge, attitudes, and values in order to perform self-regulated learning tasks. Competence is concerned with an individual's potential, which must be demonstrated in real-world situations. Initially, this concept was used in vocational education to define the relationship between education and the labor market, as well as to specify the capacities and attitudes required of graduates to perform specific professional roles. Following that, the concept of competence became widely used in general education, becoming a key concept in curriculum design and learning outcome evaluation. The main purpose in the process of personality formation in the new educational conditions is the development of the capacity for personal and professional evolution, based on intrinsic motivation, the desire to broaden one's own knowledge horizon, and so on. These conditions promote the development of personal characteristics such as the willingness to engage in independent cognitive activities, the desire for continuous exploration, and self-realization through the assertion of thought product originality. The development of a type of thinking based on the need for research, self-determination, and critical self-evaluation foreshadows the concept of asserting research competences, which is the primary objective of modern education. In general, competence refers to the set of knowledge, capacities, and attitudes that activate an individual's potential to achieve (at socially agreed-upon standards) personal and professional development objectives.

***Research competence (also used as investigative competence in some contexts)*** refers to a set of knowledge, capacities, attitudes, and specific personal qualities required in the research process, as exercised in various situations of learning through research, which mobilizes and actively reorganizes internal and external resources of students in order to achieve certain professional development objectives. According to this viewpoint, investigative competences are the result of information competences efficiency, which refers to a person's ability to operate with the information he/she possesses, to identify information sources, and to consistently capitalize on new information in the context of personal self-determination. According to Edward Deci and Richard Ryan, the authors of the theory of self-determination, "*research competence* generates a new perspective of personality motivation analysis, based on a metatheory that highlights the importance of internal resources acquired by human beings through evolution and which allow personality development through research and self-regulation of behavior through active participation in self-formation" [2]. The following fundamental psychological needs must be met in order for self-determination to occur: the need for autonomy and the need for competence.

According to this viewpoint, the need for autonomy refers to individuals' assertion of behavioral self-determination initiated by the manifestation of personal will, whereas the need for competence implies that self-determination will be achieved to the extent that the person feels he/she can perform a certain behavior and is capable of doing an effective thing. For example, positive feedback from pedagogues regarding the quality, efficiency, and independence of solving learning problems has the effect of subjectively enhancing the effectiveness of the competences specific to the research activity. According to L. V. Redman and A.V. Mory, research is "a systematic effort to obtain relevant elements of new knowledge", and "research is a careful study or special investigation that consists in the discovery of new facts in any field of knowledge" [3]. Knowledge gets full value when it is integrated into application structures, problem solving, diverse and complex situations, and when it is placed at deeper and more productive levels of learning. In this way, information learning is integrated into competence formation, and passive learning is replaced by active and interactive learning based on educator empowerment, interactive learning, problem solving, and social participation. Learning experiences that are monodisciplinary, fragmentary, and insular are decomposed and recomposed into holistic experiences that are inter- or transdisciplinary in nature. Modern civilization necessitates development based on a multidisciplinary curriculum.

***Learning oriented to scientific knowledge*** is a fundamentally motivated activity that generates intellectual energy, regulates tempo, operates with goals and objectives, rationalizes effort and time, stimulates performance, stimulates for new experiences of internalizing values, and so on. The action conditionality specific to the legitimacy specific to the motivation for development through research aims at the accumulation of previous experiences, the capacity of expression, the level of aspiration, the area of interest, and the significance of learning outcomes defined by success or failure of research actions. ***Learning through research*** is an activity based on inverse connections that transforms and ensures the efficiency of reorganization, provides quality training, and generates an information-energy balance for new knowledge. The meanings derived from the field literature on professional research competence are the result of pedagogy paradigms as models for approaching the teacher training system, which are recognized by the reference field's community of researchers and practitioners (Thomas Kuhn, 1999). In the current historical context, in postmodern (contemporary) society, we consider the "integralist pedagogical paradigm" (psychosocial), the curriculum paradigm, as a model of complex, global approach to education, focused on educational goals, and built on the interdependence of professional competences recognized by society (T. Callo, 2010, S. Cristea, 2016). The fundamental explanatory values relating to the principles, legalities, mechanisms, and factors that accelerate their functionality in the teaching profession training process and explain the development of professional research competences.

The professional training of chemistry students process outlines the contradiction between current awareness of the term investigative competence in the context of university chemistry training and insufficient training of teachers and students to organize research practice. The ***research competence includes the following units*** based on the essence of the meanings in question: (a) professional-specific, which includes basic chemistry knowledge, contemporary methods of chemistry-specific investigations, and information-processing methods; (b) scientific-rationalizing, which refers to the abilities to design and organize research experiments coherently; and (c) evaluative-experimental, which refers to methods of recording, analyzing, and interpreting the results of chemical research using modern chemical means. (d) motivational includes awareness of students' creative needs and proper perception of failure, emotional expression of constructive attitudes toward professional success, shifting attention to innovative strategies to achieve goals, motivation for self-development, and a proclivity for high levels of cooperation and professionalism.

The continuous updating of pedagogical actions in the direction of research culture formation will be reflected in the products of students' scientific knowledge as evidence of the formation of investigative competences. The efficiency of research competence formation is measured by emphasizing the following levels: minimum (meet all instructions), medium (assumes that students understand the actions specific to the stages of experimental activity within the rational approach), and high (design level – students are characterized by creative approach to research).

In order to evaluate their quality, the criteria and indicators of research competence of chemistry students will be applied (Table 1.1).

The European Union Recommendations in the formula result in priorities arising from the key competences formulated at the European level – the competence of learning to learn (the person's ability to pursue and organize their own learning according to their own needs and awareness of opportunities), initiative and entrepreneurship (the ability to turn ideas into action, innovation and risk-taking, as well as the ability to plan and manage projects to achieve goals) are two of the eight key competences, interdependent through its scientific substance, based on critical thinking, creativity, initiative, problem solving, risk assessment, decision making and constructive management of the concerns needed for integration into contemporary society [4].

Table 1.1. Criteria and indicators of research competence of chemistry students (By Xyng, 2015)

| Interferences of elements of chemistry students' investigative competence | |
|---|---|
| **Criteria / Domains** | **Indicators of research competence** |
| **1. Cognitive informational criterion** | is represented by the level of assimilation of the volume of knowledge, their systematization and interdependence, by the general culture and integration of new acquisitions in the field of professional activity, by the rational organization of the research project, analysis, interpretation, and capitalization of information in experimental research. |
| **2. The rational procedural criterion** | involves operating capabilities with the following algorithm for organizing the research activity: formulating the purpose of the experiment, the hypothesis, developing the experimental activity plan, selecting the necessary means, conducting the experimental activity, setting results and analysis of experimental data, drawing conclusions and creativity. |

| | |
|---|---|
| **3. The motivational and reflexive criterion** | awareness of the need for self-training of research competence as an expression of the professionalism of chemistry students as a result of reflection and self-evaluation, integrating the capacity for reflection and objective self-evaluation, the ability to analyze and correct autonomous learning, the tendency to success, gaining authority, enhancing self-image, building the path of continuous professional evolution. |

***The European Qualifications Framework*** defines competence in terms of responsibility and autonomy. As a result, in addition to the qualification attesting to standardized training, the distinct qualities that an individual must possess in order to adapt to new work situations have begun to be highlighted [5]. Thus, professional competence is defined as an integral system that manifests and is formed in professional activity and is based on knowledge, skills, personal qualities, and values, allowing it to establish links between knowledge and the concrete situation and determining the system of specific actions for effective problem solving.

**The operationalization of general and specific competences in the university curriculum** encourages the exploration of socio-professional learning contexts that may be beneficial in meeting students' research needs, promoting professional autonomy, or may be inhibitive (contexts that promote external control). Needs are met to the extent that they stimulate the formation of intrinsic motivation to engage in personal and professional self-development processes [6]. The models of perception of investigative competences in the scientific community are completed by new elements derived from field researchers' interpretations, and their reunion in a theoretical, articulated structure represents the "didactics of competence formation" finality. According to this viewpoint, the principles underlying the development of research competence generally refer to systemic, rational, reflexive-action pedagogical approaches. The principles of the formation of research competence aim at the norms derived from the principles of professional orientation, knowledge functionality, integrative, situational approach, and development of the research need.

In terms of synchronous-diachronic research, the general integrative purpose of university education is defined at the level of ***professional research competences (PRC)***, which aim at responsible humanistic and scientific reflection on cognitive acquisition, that is required for graduates in higher education and throughout life. The development of research competence and the ability to reflect are mutually conditioned in the pedagogical, psychological, and social plans. For these reasons, there is a need for research and the stimulation of the research culture, which is reflected in education professionals' investigative competences in accordance with the current paradigm of contemporary teaching.

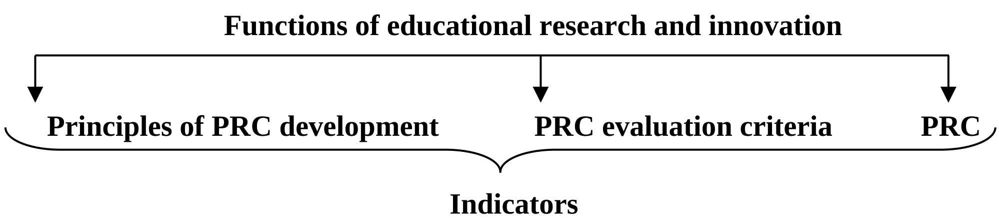

Figure 1.2. Values of professional research competence

Investigative competence is defined as the ability to conduct research and solve problems in a variety of situations by combining knowledge with social experience, as well as the willingness to mobilize and reorganize internal and external resources to achieve success. The purpose [7] is multidimensional, involving teachers in analytical, critical, and communication research, as well as personal growth. Investigative competence is the fundamental "key" to the development of field-specific competences because it promotes learning, flexibility, and competitiveness, as well as determining future professional training. It should be mentioned that "the investigative competence of teachers through the functionality of cognitive research structures contributes to the training of a constructivist teacher". The investigative activity is a creative process with reference to solving various problems, as a result, there is a transfer of values in the professional environment.

The methodology of training the research competence, approached from the perspective of outlining the rational, systematic study of university practice, conceived and realized by valuing the results of scientific research of academics, in praxiological sense (science of effective and efficient action), in terms of employing the principles objective processes, resources, actions, situations, tasks, evaluation – specific, of the way of didactic analysis and conceptualization and interpretation of problems, of effective problem solving will indisputably lead to the formation of professional research behaviors, expressed in attitudes, abilities and knowledge that certifies a level of training of students' research culture.

Investigative competences result from the efficiency of information competences. By *research (investigative) competence*, we mean a set of capabilities, possibilities, specific qualities of research, and mental operations in research that are used in a variety of situations, mobilizing and reorganizing internal and external resources to achieve predefined and established goals. Many researchers in France, the United States, the United Kingdom, Russia, and other countries have been concerned with *defining the concept of investigative competence*. As a result, the following basic elements of investigative competences were identified: knowledge, abilities specific to a field, qualities, capacities to work in a field, experience in a field, perception to do something, updating knowledge for spontaneous mastery of the situation, experience in different fields, understanding the world outside the profession, the integrated set of skills practiced in different situations, automated problem-solving strategies, way of thinking, willingness to appreciate the social consequences of one's actions, willingness to mobilize internal and external resources, high level of initiatives, intellectually conditioned social experience, personal self-realization, self-education and the ability of social diagnosis, etc.

Research competence includes the capacity to apply knowledge in a field, abilities to solve professional problems and substantiate hypotheses, to establish objectives in carrying out activities, to select and analyze the information necessary for the judicious selection of strategies appropriate to a research activity innovation. In general, the ***investigative competence*** – targets the components: motivational, personal, intellectual, cognitive-operational, and creative.

The examination of these fundamental characteristics yields the following principles specific to the process of developing students' research competence: the principle of awareness is the involvement of students in establishing the aims of learning through research problems, the research process, and its results; the principle of initiative is the accumulation of students' own experience in the field as a result of manifested initiatives; the principle of a systemic approach to the process of developing research competences – the investigation activity will only contribute to the development of research competence if it is systemic and systematic in nature; the principle of a participatory approach to research by capitalizing on resources specific to social learning; the principle of capitalizing on age peculiarities - adolescence being the optimal period in which optimal conditions for the formation of investigative skills are created; the principle of capitalizing investigative potential; the principle of ensuring the reverse connection through periodic metacognitive activities. Metacognitive activities stimulate the process, improve its quality, and foster in students the ability to manage their own research. The application of these principles ensures that students transition to independent learning. When organizing investigative activities, the professor emphasizes developing research motivation, ensuring the balance of novelty, originality, and importance of the researched problem, selecting methods based on the proposed purpose and objectives, and adhering to the research project model accepted in the academic community.

Special attention is paid to interactive pedagogy, which is integrated through modern educational technologies, including information and communication technologies, to affirm the education focused on competences formation [8]. The revealed pedagogical and socio-cultural context explains the didactic methodology, which is characterized by processes aimed at the development of some useful professional competences for the research activity. The key to rapid socioeconomic evolution and the accumulation of large volumes of new knowledge is to insist on teaching students how to select the necessary information and adapt it appropriately to solve concrete problems. In recent decades, the transition from information education to competences-based education has necessitated a rethinking of mechanisms for transferring theoretical knowledge into practical activities by asserting the competences required in the professional services market and effective integration into the future society.

For these reasons, *professional competences* are expressed in a system of attitudes and capacities that allow the use of knowledge, their transposition into various situations and unique conditions of activity, to achieve the professional roles required at work according to the level of quality specified in occupational standards, "professional capacity results from the harmonious combination of attitudes, knowledge, and capacities in order to achieve the expected results". Demonstrating professional competence in an occupation involves "using specialized knowledge in various practical situations in an original way; demonstrating specific capabilities; making decisions and demonstrating creativity in professional actions; working with others as a member of a team; effectively communicating; adapting to the work environment through specific approaches to the professional community and dealing with unpredicted situations". According to M. Minder, "capacity allows the acquisition of knowledge, being the transdisciplinary mental activity that allows the mobilization of competence in authentic professional activities" [9].

In this order of ideas, *research competence* and *entrepreneurial competence* play a special role in the field of Natural Sciences, the training of which provides additional professional values to young specialists while contributing to the community's scientific and economic development. Content development of the Chemistry curriculum in the Republic of Moldova, in the last three decades, has generated a shift in emphasis on the formation of research culture [10].

The rapid technological-scientific changes brought about by the amplification of scientific communication contribute to the reconceptualization of new dimensions of the vocational training system, ensuring competitiveness in the field of educational services. To compensate for the deficit of depletable natural resources, the future knowledge-based society will employ efficient technologies in a variety of fields. To accomplish this, the personality must be self-taught, demonstrating the ability to acquire new knowledge and reform it for the context in which it operates. This trait must be cultivated throughout one's life. Because the educational system is one of the factors that has a decisive impact on the formation of personality, effective methodologies for adapting educational philosophy to the needs of the labor market are required. The value of specialists in this context is determined by their ability to solve real-world problems. It is necessary to assert young people through a flexible, creative, and innovative thinking style, which would solve problems and develop professional competences through new valuable experiences in the field. It is critical that the educational process has a formative character for students, both for society as a whole and for each individual member of the community. Interactive methods based on investigating different processes, discovering new knowledge, and drawing conclusions about the importance of the information studied to solve life's problems are among the most effective strategies.

Because research is one of the most complex and subtle activities, research training is a complex and dynamic process that is constantly evolving. In this process of self-education, research-oriented education largely involves motivation for self-training. The research entails methodological initiation, general and specialized culture, personal and professional qualities of trainers, and training of students in investigative skills: to judge independently, document, find alternative solutions, formulate, and solve problems, creativity, perseverance, interest, and intellectual curiosity. In the postmodern view, research is a managerial management activity that is designed and carried out in order to regulate / self-regulate the didactic activity, allowing the notification of new reports, relevant to pedagogical actions, and serving as the foundation of optimal solutions to problems in vocational education.

In the early stages of the university education process, research can be based on general cases; later, it will be developed on specific cases. According to the constructivist paradigm's theoretical conceptions, students' creative abilities can be formed in the context of independent activities of searching, discovering, and solving problems that are based on students' ability to think logically, imaginatively, and creatively. Each problem-solving exercise helps to develop the ability to formulate assumptions and forecasts, which will later be validated by experimental data and evidence of the viability of the initial assumptions. This process clearly contributes to the accumulation of new information and operational acquisitions, as well as the development of logical thinking and conscientious learning. *The development of research competence eventually leads to the formation of an innovative research spirit.* Students will be deeply involved in the experimental activity to ensure a process of fundamental development of research competence, understanding the situation, as a whole, not just in relation to a separate object, but also the connections it has with other objects and phenomena. As a result, in each case, the causes and effects of these research phenomena and processes must be thoroughly examined.

The specificity of the pedagogical approach in research training conditions aims at intentional transformations in the personality structure. The main stake of education through research and for research is the trainer-formable relationship and the adapted refinement of specific didactic strategies: comprehension strategy and interpretation strategy are essential in capturing the functional interdependencies between the variables of the educational phenomenon to clarify the mechanisms. The comprehension strategy makes it easier to obtain information by asking questions like: why? how? what are the causes? In this order of ideas, the explanatory strategy leads to the elaboration and substantiation of some conceptual structures, while the understanding strategy facilitates the capture of deeper meanings. It has been found that each research experience has a different impact on the process of personality formation. Individual preferences (sometimes of a subjective nature) influence the research trajectory, which can result in different goals for the process of developing investigative competences. When results differ from expectations, contradictions emerge, resulting in new problem situations. Occasionally, an unexpected result can produce more valuable effects and deeper studies than easily predictable results. One of the developmental aspects of scientific research is the development of a complex affective competence - intuition - along the way. It enables investigations with prognostic results, because competence is defined as the capacity to meet some complex demands by correlating personal skills and attitudes in a given context, in addition to knowledge and skills. To be competent, then, means to apply the system of knowledge, abilities, and values acquired to achieve a specific result in the field of the profession.

The emphasis shifts to research-based learning in the context of curricular renovation and reshaping the educational process, with the purpose of integrating students into professional affirmation activities through creative products. Research ensures that students complete creative tasks. The research competence serves as the foundation for the development of other chemistry-specific competences while also serving as one of life's essential competences.

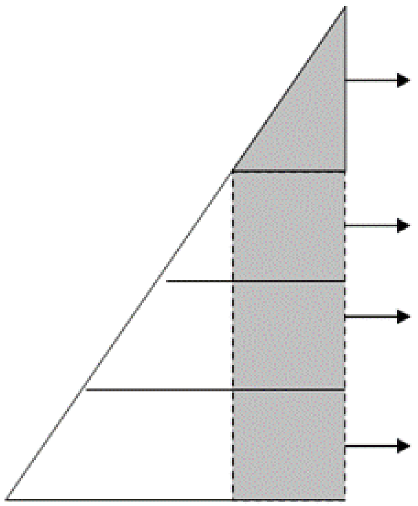


Figure 1.3. The path of evolution in the development of students' research and innovation competence

One of the current scientific concerns of professional pedagogy is the clarification of the scientific meanings of chemistry students' professional research competence and the path that it takes in a university context. In our opinion, investigative competence facilitates the effective realization of the research culture's functions: heuristic, illustrative, informative, projective, evaluative, managerial, normative, stimulating, and developmental in the context of professional action innovation. We define chemistry students' professional research competence as a RC entity that allows for the valorization of professionalism in the conceptualization and autonomous organization of research projects with innovative results in the field of professional training. We can trace the evolution path that explains the dynamism, adaptation to curricular requirements, and anticipated resolution of training directions by using the design of the elements of research competence.

The conclusion that is required in the context of approaching the evolutionary path of research competence training refers to university teaching technologies that are recommended for this purpose and include the main components of the educational process: dialogued-problematized teaching-learning, problematic teaching-learning, teaching-learning modeledproblematized, algorithmic-problematized teaching-learning, problematized-contextual teaching-learning, problematized teach-learning, problem-based teaching-learning on modules, problem-solving-computerized teaching-learning. The didactic targeted strategies are a combination of methods and means of training that predominate in a specific form of independent study organization. The heuristic method and conversation, for example, predominate in the dialogue-problematized university teaching-learning-evaluation. In this sense, teaching methodology is a constant field of innovation, with creativity becoming an essential virtue of both teachers and students. Students engage in creative and fertile interactions in learned professional behaviors during the teaching process.

University teaching technology is an approach used by university teachers and refers to the typology of objectives, which give them hints for designing teaching-learning-assessment and regulating this process, identifying each operational educational objective. It is defined from the perspective of the pedagogical intention of research training, with the mental processes of students who are actively studying on their own, as well as with techniques that are unique to the many academic fields. The creation of research-driven teaching methodologies is necessitated by the design of educational technologies.

The efficiency of the university teaching activity is determined by the relations of complementarity between its constituent elements and by the pedagogical experience of the teachers and by the experiences of knowing the students. The teaching-learning-assessment methodology is found to be a broader concept than didactic technology as it aims, including the research activity carried out by specific didactic strategies as action approaches and flexible operational. As a result, there are no contradictions between the methodological, didactic, and technological approaches. These are coordinated and linked to objectives and circumstances that establish the framework for teaching and fostering learning, modifications in attitudes and behaviors in different, specific instructional environments. As a result, the emphasis is placed on an orientation sense of the best path to take in order to accomplish the goals, didactic tactics, and a system of multidimensional and interactive operations, supported by flexibility, adjusting to the scenarios and conditions appeared spontaneously.

***The formation of research competences*** necessitates a careful selection of teaching methods. The research project is a method whose application results in products that result from the transfer of knowledge and capacities. The project promotes interdisciplinary approaches, fosters creativity, and strengthens social competences. It is built through problematization, giving researchers real tools for solving authentic problems while stimulating learning. Following the research, students showed the effectiveness of investigative competences in promoting academic and social success [11].

This adaptive realignment is dependent on teachers' creativity and spontaneity in identifying flaws and correcting errors. Research training is not a universal method that can be applied to everyone in the same way and under the same conditions. It must become a leveraged method for teams of researchers in various professional contexts, adapted to clearly defined goals and research methodologies, producing valuable and authentic results that impact the professional community's interest.

Table 1.2. The advantages of training research competence by amplifying the professional competences of chemistry students

| **Advantages** |
| --- |
| ✓ in-depth knowledge of the field;<br>✓ accessibility to information resources;<br>✓ professional competitiveness;<br>✓ professional mobility in context;<br>✓ streamlining learning activities;<br>✓ development of communication competences and individual study;<br>✓ strengthening scientific investigation abilities;<br>✓ developing motivation for lifelong learning;<br>✓ stimulating innovative thinking;<br>✓ exploring professional creativity;<br>✓ affirmation through professional culture, in general, and culture of research and in particular innovation. |

The systemic approach, interpreted in the field literature as a set of interdependent elements, was investigated in the pedagogical conceptualization of the term research culture. “The research culture”, in our opinion, “represents a system of convictions regarding investigative activity, personal qualities, and investigative competences, reflected in the fields: philosophical, metacognitive, heuristic, methodological, innovative, and ethical, the interdependence and unity of which ensures the integrity optimal results of the investigative potential in the socio-educational framework”.

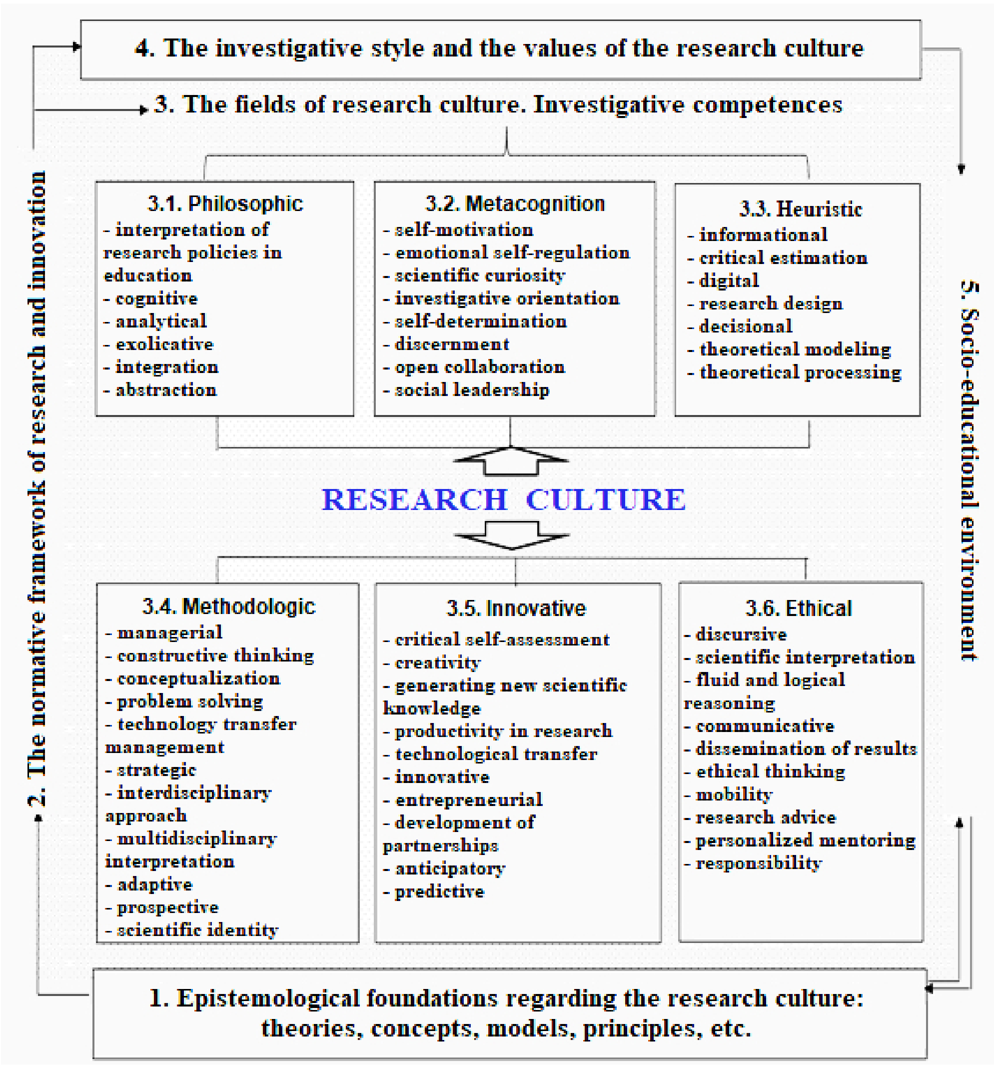


Figure 1.4. The conceptual model of research culture

The epistemological foundations of research culture refer to a system of scientific knowledge interpreted from the perspective of research functions and principles, theories of research and innovation, paradigms and models that theoretically found the model descriptive by the principles generating positive transformations (Figure 1.4). They have an organizational personality that hierarchizes the structural elements, a functional and dynamic personality, a heuristic personality that generates new connections and interdependencies, and an integrative personality that develops the meaning of the included components. Research culture fields (philosophical, metacognitive, heuristic, methodological, innovative, and ethical) reflect the quality of investigative skills validated in the socio-educational environment, which define the investigative style through research culture values.

The values of research culture are approached in order to delimit descriptors of the formation of investigative competences, as an expression of research culture and refer to the valorization of principles: awareness of the importance of research, involvement in establishing learning goals through research, initiative, systemic and systematic approach in the formation of research skills, the principle of participatory approach in research through the use of specific resources, the principle of participatory approach in research through the use of specific resources, the principle of participatory approach in research through the use of specific resources.

## 1.2. EDUCATION POLICIES FOR THE PROMOTION OF RESEARCH CULTURE

Examining international and national policies promoting professional research culture reveals that this process aims to train a competent, efficient, constructive, and competitive specialist in the context of the knowledge society. In response to societal challenges, contemporary society is experiencing an obvious crisis of values, and higher education through research is now acting in the direction of ecologically sustainable cultural, socioeconomic development of communities and nations. Higher education is committed to the creation of a global education system through improved teacher education, curriculum development, and educational research. The Education Code of Republic of Moldova states that research is required in higher education and is "carried out for the purpose of producing knowledge and professional training of highly qualified specialists" (Chapter IV. Scientific research in higher education, Art. 116. Scientific research) [12].

The implementation of the reform envisaged in the Bologna Process at the European and national levels aims at rethinking the curriculum from the perspective of building student-centered learning situations, on the formation of competences in the direction of lifelong learning. Given that student achievement is one of the indicators of educational quality, concern for their academic success becomes critical in the context of higher education reform.

The Council of Europe and the Steering Committee for Higher Education and Research should use their position as a pan-European values-focused platform to ensure that the essence of university values is rooted in the European Higher Education Area and to assist in finding appropriate ways to adapt to societal changes. By involving decision-makers in driving research agendas, we can improve the quality, relevance, and availability of university research to inform policy [13].

According to the UNESCO General Conference's Recommendation concerning the Status of Higher-Education Teaching Personnel, higher education institutions, their staff, and students must maintain and develop their basic functions: teaching and research; increase the efficiency of critical functions and anticipate educational trends; and propose solutions to problems that affect the well-being of communities, nations, and society in general [14]. Article 5 of the World Declaration on Higher Education for the Twenty-First Century: Vision and Action emphasizes that "advancing knowledge through research in science, the arts and humanities and the dissemination of its results" [15] is a basic function of all higher education systems. Curriculum must promote and strengthen innovation, interdisciplinarity, and transdisciplinarity with specific goals.

An appropriate balance will be struck between basic and special research; (b) Institutions should ensure that all members of the academic community engaged in research are provided with appropriate training, resources, and support; and (c) Research must be enhanced in all disciplines, as reflected in both public and private sources. The expansion of research capacities within higher education's research subdivisions is critical.

Professionalization for teaching is a common theme in pedagogical theory and practice research. The requirements of modern society are constantly evolving and pose new challenges to contemporary specialists, most notably the development of key competences that students must possess as a result of their university studies. Higher education places a premium on research. According to the Berlin Communiqué (2003), "education and research are the pillars on which the knowledge-based society is built" [16].

European policies on education research describe educational processes, with a focus on the connections between the educational environment and the labor market. Horizon 2020, the European Union's Framework Program for Research and Innovation, aims to support training through research and innovation, with a particular emphasis on formation of innovation competences [17].

According to the UNESCO Recommendation on the Status of Teachers in Higher Education Institutions, "higher education and research constitute an exceptionally rich cultural and scientific asset that governments and important social groups, such as students, industry and labour, are vitally interested in and benefit from the services and outputs of the higher education systems, recognizing the decisive role of higher education teaching personnel in the advancement of higher education, and the importance of their contribution to the development of humanity and modern society, recognizing the decisive role of teachers in higher education institutions and the importance of Higher-education teaching personnel who should play a significant role in determining the curriculum". It mentions the academic community's vulnerability, which could undermine academic freedom, noting that "the right to education, teaching and research can only be fully enjoyed in an atmosphere of academic freedom and autonomy for institutions of higher education". "Research, within the context of higher education, means original scientific, technological and engineering, medical, cultural, social and human science or educational research which implies careful, critical, disciplined inquiry, varying in technique and method according to the nature and conditions of the problems identified, directed towards the clarification and/or resolution of the problems, and when within an institutional framework, supported by an appropriate infrastructure". "Higher-education teaching personnel have a right to carry out research work without any interference, or any suppression, in accordance with their professional responsibility and subject to nationally and internationally recognized professional principles of intellectual rigour, scientific inquiry and research ethics" [17].

The constructivist model of research culture's relevant dimensions are reflected in the design of teacher training policies. The policy document design guidelines aim to: take into account the representations, attitudes, values, knowledge, and curricular practices considered effective in a specific socio-cultural context; reconfigure curricular design in accordance with the psychological foundations of constructivism; and analyze the implications on educational finalities and student training profiles; establishing a self-generated reflexive attitude toward the educational process; achieving an integrative approach regarding the roles of the teacher in contemporaneity, given that the understanding of the multidimensionality of the roles determines the curricular coherence; implementation of research methods that are not only the attribute of experts in the curricular field, but even a feature of the teacher's behavior in a new context of professionalization; implementation of an approach that reconfigures the connection between epistemological-pragmatic / methodological; updating professionalization from the perspective of competences development (the role of establishing and taking into account the use of the portfolio of professional competences).

The Republic of Moldova's Code on Science and Innovation (2004) puts emphasis on the fundamental concepts of research, innovation, technology transfer, and so on, and describes state policy in the field of research and innovation; mechanisms for administering, funding, and evaluating research; the legal status of the scientific researcher, and so on [18].

The existence of positive attitudes toward the constructivist model justifies the opportunity to incorporate thematic modules that stimulate the formation of research culture in accordance with contemporary paradigms and curricular models into initial and ongoing teacher training. Investing in the quality of teacher education is a long-term investment that has a significant impact on the creation of a professional development continuum.

With the Republic of Moldova's admission to the Bologna Process (2005, Bergen Summit), it became mandatory for university cycles I (bachelor) and II (master) to conduct research in order to develop the thesis of graduation of the study cycle. This triggered a chain of events that resulted in the promotion of research culture elements not only among teachers, but especially among students.

The draft Education Strategy 2030 outlines the strategic directions of action required to solve problems and achieve educational development objectives. The strategy defines the conceptual, methodological, teleological, axiological, and praxiological framework for medium and long-term education development. The integration of education and research in higher education aims to strengthen and ensure the competitiveness of university studies; to align educational policies with labor market demands; to promote innovative entrepreneurship, and so on.

The opportunity to promote research culture arises from the normative challenges of contemporary education on a global and national scale, which registers the integration of investigative skills in professional qualification standards, valued as an indicator of teaching professionalism, and highlighting information processing capabilities through modern search and processing methods. Interpretation and adaptation of research findings for professional purposes. The importance of research is determined in this order of ideas by the objective need for scientific foundation and the development of a system of preparation for research activity through the formation of investigative competences subscribed to the research culture. Professional competences are required for innovative activity, complex problem solving, team action coordination, critical thinking, social competences, innovative creativity, professional assertiveness, quality control of innovative activity, and so on.

The challenges of the social context in promoting research culture are based on:

a) The complex phenomenology of research culture is an area of eternal interest in the scientific community, frequently approached, especially from the perspectives of philosophy, sociology, culturology, and so on. The pedagogical essence of research culture, which emerges from the evolution of pedagogical thinking, is intriguing.
b) The difficulties of training / self-development of teachers' and educators' research cultures result from the pedagogical responsibility of forming students' general and professional cultures in the knowledge society. For these reasons, educators must cultivate a research culture that includes continuous self-improvement for teaching and research, affirmation by capitalizing on teaching research results, pedagogical creativity in the sense of training through research and development initiatives, and social entrepreneurship.
c) Research in higher education is under pressure from university research management [19].
d) The trend toward higher education's competitiveness leads to an increase in research output, which is recognized as critical for the academic success of the modern university: institutional reputation – among research universities, institutional reputation is closely related to research productivity. "*Research productivity facilitates the growth of educational institutions' reputation*" [20]; institutional staff promotion, determining performance evaluated through publications [21].

The normative acts of the Republic of Moldova that regulate the development strategy through research-innovation of education contain provisions that imply the development of the research culture:

a) The priority extension of fundamental researches as a basis for the production of new scientific knowledge.
b) Ensuring the training of qualified specialists and scientific staff on the basis of new results in contemporary science that stimulate technological progress.
c) The effective use of education's investigative potential to solve socioeconomic and cultural problems.

The National Program in Research and Innovation for the years 2020-2023 encourages the development of collaborative innovation platforms centered on research and innovation infrastructures: 4.1. *innovative development for the transfer of university scientific results to potential users* and 4.2. *increasing public awareness of the role of research and innovation in addressing societal challenges and generating prosperity* [22]. The National Program in Research and Innovation for 2020-2023 aims to promote research excellence, increase the efficiency of the national research and innovation system, and ensure optimal conditions for the generation and application of new knowledge derived from basic and applied research.

Fundamental and applied research, innovation, and technology transfer will all help to increase the synergy between research fields and labor market needs. The national research and innovation program for 2020-2023 is based on the following principles: increasing the synergy between research fields and labor market needs; intensifying international cooperation in multidisciplinary and cross-border networks; strengthening human capital and raising interest in research and innovation to attract talent; and the principle of creating collaborative innovation platforms organized around research and innovation.

In line with the aims of higher education institutions, the essential guidelines for modernizing research include bringing professional knowledge closer to scientific knowledge, while also adapting to the social challenges unique to education. The constant renewal of research methodology in response to the evolutionary tendencies of education sciences ensures the generation of new scientific knowledge and innovations that would meet the social needs on the agenda of the education system, as well as the use of existing knowledge in unique experimental situations that lead to the development of university intellectual infrastructure through: dictionaries, critical or treated editions, research databases put at the service of the academic community. To support university teachers' motivation for research, it is necessary to valorize scientific products through innovative transfer in didactic activity, actions that contribute to the dynamization of the evolution in the university career.

*The following scientific knowledge principles serve as the foundation for the relevant normative acts*: the principles of realism, determinism, and cognoscibility [23]. A set of principles govern the development of research competence: the principle of research activity awareness – involvement in establishing the purposes of learning through research of existential problems; the principle of research activity initiative – the style is learned by accumulating research experiences thanks to manifested initiatives; the principle of systemic and systematic approach in the formation of research skills; the principle of participatory approach in research by using specific resources; the principle of capitalizing on the investigative potential of the personality and the group achieved by generating the optimal conditions for the formation of investigative competence; the principle of ensuring the reverse connection through metacognitive activities that stimulate the amplification of the quality of research management competence.

An examination of the evolution of curricular provisions in various European countries and the Republic of Moldova over the last few decades reveals an increasing importance of research competence in the training of chemists in both general and university education [10, 24].

The experience of prestigious universities around the world shows that including students in various research projects that use modern research methodologies develops professional competences in the field and generates significant ideas and results [25].

Consistent reconceptualization and application of coherent strategic policies for managing university research quality involves increasing academic staff motivation for research and the transfer of innovations in professional activity. “The evolution of higher education’s mission from teaching-research to entrepreneurship strengthens universities’ role as providers of scientific information”, trying to encourage “innovative transfer related to today’s social challenges” [26].

The realization of the function of research and innovation for the generation of new scientific knowledge has become an essential preoccupation of higher education in the context of the contemporary university’s crisis. From the perspective of the scientific community’s interest on a global and national level in resolving the complex problem of education, in a prolonged “global crisis”, pedagogical researchers are asked for viable strategic solutions, with contemporary reality demonstrating the need for new approaches to monitoring investigations. Teacher trainer must conduct research in order to stay current on developments in their academic field. There is also strong evidence that teachers and teacher trainer must be ready to engage in investigative practice, which includes the capacity, motivation, and opportunity to apply research competences to investigate what is being investigated. They know what works well and what doesn’t in their own practice. High-performance education systems demonstrate that this type of investigative practice necessitates training through carefully designed initial teacher training programs that enable trainee teachers to integrate knowledge from academic study and research into the practice of education throughout their professional career, thereby incorporating disciplined innovation into professional culture.

## 1.3. SOME PECULIARITIES OF THE FORMATION OF RESEARCH COMPETENCE

The introduction of competences as school curriculum finalities in high school and gymnasium education represented a methodological opportunity for pre-university education. Offering an articulated theme to the didactics issue in the existence of competences as educational finalities [27]. This situation emphasizes the importance of finalities in the context of competence-centered teaching, and it stimulates and supports concerns about the development of research competence in order to ensure students' academic success and the prevention of academic underachievement. The student-university teacher partnership is critical to the student-centered education philosophy [28].

A number of factors influence modern didactics, conditioning the reconfiguration of trends in the organization and development of teaching activities. According to educational policies, learning activities in school curricula are oriented toward finalities such as the elaboration of various products, opportune to capitalize on competences in certain thematic topics of the content units. The teacher's role in implementing the educational approach is to plan learning activities and select the most effective teaching strategies based on the modeling factors of the learning environment. Self-regulated learning is concerned with the cognitive and metacognitive strategies applied by students in vocational training, as well as the managerial strategies applied by students in the evaluation of self-training. Recent self-regulatory learning models emphasize the integration of motivational and cognitive learning and involve students using various metacognitive strategies to control and self-regulate learning.

The quality of higher education is determined by the quality of specialist training, which is integrated through a complex system of professional competences required to meet social challenges. The initial training of students is a priority in the sphere of university concerns. A system of philosophical issues about the nature of professional knowledge and the nature of research, practical wisdom, and critical reflection, explicitly clarifying the relationship between research and professional practice of teachers, is at the heart of understanding "research-based teacher training". Reflective learning is promoted in higher education because many learning experiences are unplanned and experiential, with reflection being the key to this type of learning. The authors use critical thinking to evaluate reflective learning, which entails asking probing questions about the text and coming up with original suggestions that aid in grading students [29].

In a student-centered environment, teacher authority and student autonomy are both balanced. The role of university teachers in the direction of asserting themselves through their scientific products as models of professional thinking is substantially changing in the setting of student-centered education. They transform from being a source and transmitter of knowledge to a mentor, facilitator, and creator of the educational experiences of pupils. Establishing a healthy balance between the authority of the teacher and the level of student autonomy has significant implications for students' ability to assume responsibility for learning outcomes and advance toward intellectual maturity.

There are thus several strong justifications for schoolteacher trainers to rely on research findings to refresh their professional knowledge and to partake in research-related activities in order to broaden and deepen their professional training. In this sense, the initial training of chemistry students involves certain components that have the status of decisive factors in the educational process by designing the following objectives: to perform a scientific analysis of significant chemical and socio-economic problems, to solve problems in different departments of chemistry, to be able to put chemical experiments, analyze their progress and formulate the appropriate conclusions, recognize the classes of chemical compounds according to their properties, synthesize and apply in practice chemical compounds, apply efficient methods of synthesis and processing of necessary chemical compounds, to apply the advanced knowledge in chemistry at his disposal in everyday life, to strive for continuous self-improvement in daily work, to contribute to raising the level of chemical and ecological culture in the given place, to a caring attitude of society towards the environment, to estimate the results of the activity in the field of education chemistry and solving the ways of modernizing these activities.

The following models serve as the foundation for the *Concept of University Innovation Activity*:

- *The "pyramid of knowledge transfer based on training through research and innovation" model* implies the need for a systemic and coherent approach to scientific, educational, and innovation activism of university teachers and promotes the integration of innovation in higher education because of the accelerated pace of new knowledge production in contemporary society. In the knowledge society, research processes, technology transfer, and university training are interdependent and synergistic. The activity of innovation requires the efficient completion of these processes. According to the model's authors, innovative activity allows academics to integrate into the scientific community and obtain the status of scientist.
- *The model III mission of universities* is based on the approach of the mission of universities to generate and transfer new knowledge in the context of the two classic functions of universities: (a) training of highly qualified specialists, (b) scientific research, and (c) knowledge generation and transfer.
- *The open innovation model* – a new paradigm for the development of innovative entrepreneurship that implies a flexible policy in relation to research results and intellectual property by capitalizing on external sources in the implementation of innovative projects. The model allows obtaining the maximum efficiency from the collaboration in order to create and develop innovative projects.
- *The model of dual-oriented university innovation management:* toward internal innovation process management and external validation of scientific products in a socioeconomic context.
- *The attractiveness model of innovative university management* oriented toward the promotion of research culture [30].

The teaching strategies used in higher education for the development of research competence are the result of the criteria considered and aim at: (a) strategies focused on teaching action (discursive and explanatory strategies, discursive and conversational strategies, discursive and demonstrative strategies, algorithmic strategies (prescriptive); (b) strategies focused on learning activity and teacher-student interaction: strategies based on research and exploration (investigative research), strategies based on textbook exploitation, strategies based on different training media exploitation, problem-solving strategies, strategies based on model use, strategies based on practical work, strategies based on project design, strategies based on information and communication technology, strategies based on information and communication technology); (c) mixed strategies; (d) integrative strategies (holistic strategy); (e) evaluation strategies [27].

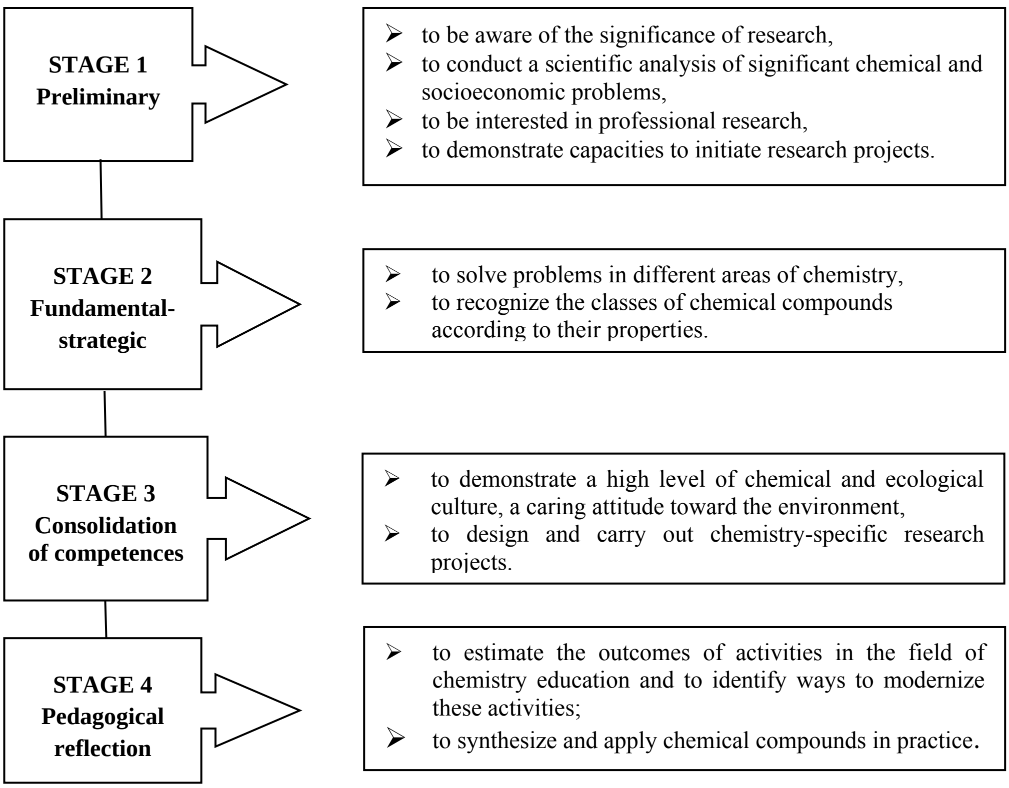


Figure 1.5. The approach of achieving the objectives of the initial professional formation of chemistry students

The concept of professional competence, developed in the context of teaching-learning-university evaluation as a result of the application of specific strategies for teaching chemistry, expresses the high level of qualification and professionalism, manifested in professional situations in the form of actions aimed at achieving a purpose or solving specific problems. The assertion of professional competences becomes a priority in the context of achieving a quality education through the integration of knowledge (cognitive domain), capacities (psychomotor domain), attitudes, and values (affective-attitudinal domain).


Figure 1.6. The classic structure of competence
(adopted after D. Potolea, S. Toma [31])

Based on the above, we found that each component of chemists' professional competence performs the following functions: motivational – stimulation, motivation; cognitive – information and orientation; action – translation and regulation; and reflexive – self-analysis. The didactic macrostrategies, which are defined as executive processes in relation to cognition and metacognition and have a high degree of generalization, are strategies that ensure students' long-term active participation in the educational process and the coordination of self-directed learning activities with other activities. This category includes independent study activity monitoring, control, review, and self-testing. Students' learning styles, according to the same classification, reflect central strategies that are dependent on attitudinal and motivational learning factors, as well as autonomous learning planning [32]. "Designing the university teaching activity from the students' learning needs; training in teaching through interactive strategies; encouraging autonomy in learning; and using a variety of assessment and self-assessment methods" is a priority in teacher initial professional training. Figure 1.7 represents the targeted components of research competence that will be developed during the process of formation chemists' professional competence.

The teacher's direct involvement in pedagogical research, the systematic combination of teaching and research, can only have positive effects on students' continuous training and self-training, as well as a positive impact on his overall personality training [33]. Cooperative learning is a pedagogical strategy in which students work in microgroups to complete learning activities.

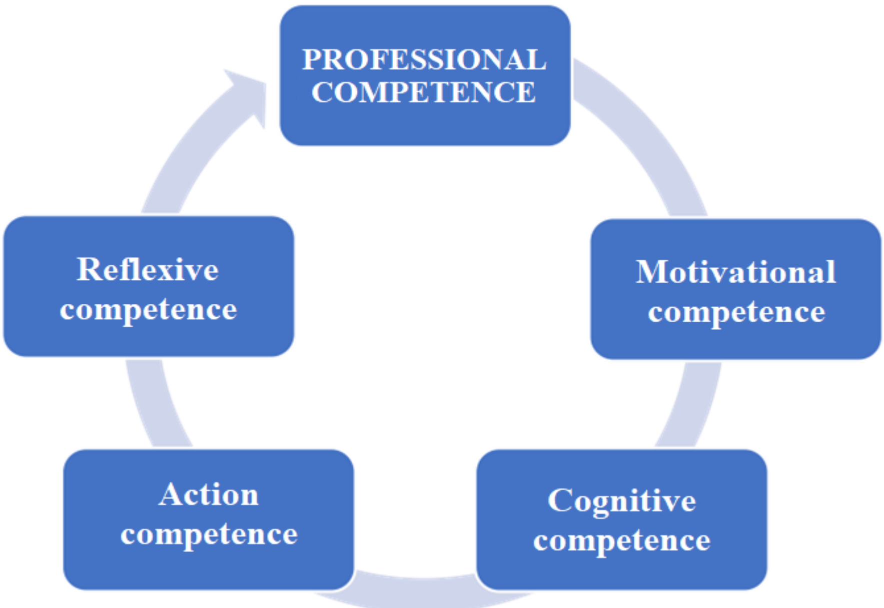


Figure 1.7. Circuit of professional competence development according to competence standards

In the National Qualifications Framework for Higher Education in the Republic of Moldova, the following general and specific competences are listed in the field of vocational training 050 Chemistry (Table 1.3):

Table 1.3. General and specific competences
(vocational training field 050 Chemistry)

| General competences | Specific competences |
|---|---|
| ✓ analysis, synthesis and communication of scientific information in the field of chemistry;<br>✓ efficient use of information sources and communication and training resources;<br>✓ application of theoretical knowledge about the composition, structure and properties of chemical compounds in solving practical tasks;<br>✓ identifying problems, formulating and solving them;<br>✓ generating new ideas and creative solutions in solving problem situations;<br>✓ application of efficient and responsible work strategies, punctuality, seriousness, and personal responsibility. | ✓ monitoring chemical properties and phenomena by observation and measurement;<br>✓ implementation of scientific and practical solutions in solving experimental problems;<br>✓ collecting, evaluating, interpreting and synthesizing chemical information and data to solve new theoretical and practical problems;<br>✓ safe use of chemicals, taking into account their physical and chemical properties, including any risk involved in their use;<br>✓ guiding laboratory processes and the use of devices in the activity of synthesis and study;<br>✓ highlighting the correlation composition-structure-properties of chemical combinations;<br>✓ use of appropriate methods, instruments, equipment and technologies for measurement and monitoring activities;<br>✓ interpretation of data from laboratory measurements and observations and their classification;<br>✓ application of theoretical knowledge to solve practical and quantitative problems practical and in everyday life;<br>✓ selecting the most appropriate methods for solving new theoretical and practical problems;<br>✓ monitoring chemical properties and phenomena by observation and measurement;<br>✓ oral and written presentation of the scientific material and justified argumentation of one's own opinion; |

| | |
|---|---|
| | ✓ synthesis, evaluation and interpretation of data in the field of inorganic, analytical, organic and physical chemistry;<br>✓ adequate use of theories, principles, essential methods related to the field of chemistry;<br>✓ highlighting the correlation composition-structure-properties of chemical combinations;<br>✓ communication of scientific information to specialists and the public. |

In a constructivist sense, university teachers determine students to become responsible and participate in the process of professional self-training, through problem solving, explorations, and research in new learning contexts, by capitalizing on cognitive and metacognitive strategies. Starting from the premise that university teachers play a critical role in shaping students' learning environments, it is necessary to develop the following competences to support cooperative learning: organizational competences, scientific competences, psycho-pedagogical competences, methodological, managerial, and psychosocial competences. Cooperative learning values intellectual and verbal exchanges and is based on a learning logic that considers the viewpoints of others. From the perspective of modern university education, the initial training of chemistry students will ensure:

- understanding the ways in which, in the didactic processes, the ideas, the behaviors of the individuals are interinfluenced in a beneficial sense for all the participants, directly or indirectly, in the long-term educational processes;

- the creation by specialists and the understanding by those interested - managers, employees – of psycho-pedagogical, psychosociological theories;

- understanding the way in which various group processes are carried out - group membership, roles, norms, cohesion factors, group thinking, group performances;

- outlining the active prosocial behaviors, necessary in the future for integration in the knowledge-based society;

- developing the role of self-knowledge and mutual knowledge as a premise for the formation of a certain professional attitude in the teaching career;

- the choice and appropriate use of the proposed purposes, of the most appropriate training methods (individual or group, active or passive);

- social and cultural responsibility of both trainers and students;

- development of professional ethics specific to the teaching profession.

Theoretical generalizations based on the definition and structure of professional competence allow us to identify the following specific professional competences required for chemistry students, which we believe can be formed and developed in an interdisciplinary context:

- *the competence of investigation / research* – represents the application of the methodology of scientific investigation in the field of chemistry in various professional contexts;

- *professional communication competence* – involves making appropriate decisions in order to achieve established objectives and obtain effective results;

- *digital competence* – involves the knowledge and efficient use of general information technologies also specific to chemistry in professional activity;

- *ecological competence* – aims at forming a culture of environmental protection through responsible behaviors and appropriate decisions regarding the state of the environment;

- *the competence of continuous professional training* – supposes a good self-knowledge in order to identify one's own vocational training needs and to continuously develop one's professional competence.

The competences in question can be classified as follows:

**a.** ***The investigative competence*** of chemistry students elicits the investigative potential of students as expressed in the design and conduct of experiments as a method of scientific investigation and as a method of knowledge. The major purpose of scientific research is to produce new findings by developing theories, laws, and knowledge, among other things. The formation of this competence has its roots in natural science epistemology and involves the exploration of reality through challenging activities in order to obtain new scientific truths. The investigative competence ensures knowledge of reality. The experiment is the method used in chemical investigation to demonstrate truths and develop students' scientific thinking.

**b. *Digital competence*** – due to the rapid pace of society's development, the integration of information and communication technologies (ICT) that has allowed the penetration of chemistry in various areas of human activity. Chemistry, because of its interdisciplinary nature, contributes to the development of competences in almost all fields of activity: social, scientific, and so on. Chemistry also contributes to the development of skills using various educational software, modern methods of research and analysis (X-ray diffraction, NMR, quantum calculations, and so on), as well as the development of interpersonal competences and the ability to work in international companies through knowledge of a foreign language and access to electronic information sources. Promoting contemporary education policy through the UNESCO project ICT competency standards for teachers The reference of teachers through ICT (2011), Standards of digital competence for teachers (2015) emphasizes the critical importance of streamlining teacher training through ICT resources as a strategy to improve the quality of competences required for the teaching profession in terms of digital communication for information management, creation of digital educational content, implementation of school management applications, educational content management systems (ECMS), and the use of digital equipment in education in accordance with ethical and legal standards in the digital space [34].

**c. *Professional communication competence*** aims at the level of mastery of a system of specialized scientific terms that reflects the cognitive process of possessing and processing scientific information. Language expresses personality traits, interests, desires, and cognitive system development level. Language organizes thought, systematizes acquired knowledge, and thinking enables the necessary organization of language. Students' speech reflects the peculiarities of their professional thinking. What the student learns through training activities implies a continuous intervention of thought that selects certain forms and introduces certain changes. There are various ways for students' professionalism to be expressed in the interaction between thinking and language. As a result, the student's communication competence is integrated with his or her gnoseological competence, which is later developed through memorization, differentiation, classification, and interpretation. Thus, we can determine the cognitive progress of the student based on communication competence. In the last two decades, special attention has been paid to interactive pedagogy, which has been integrated through modern educational technologies, including new information and communication technologies, in the context of competence-centered education. University pedagogical education is renewed as a result of research.

**d.** ***Ecological competence*** refers to environmental education, which plays an important role in restoring man's harmonious connection with nature. Protecting the environment entails addressing the issue of pollution, regardless of its source, which endangers agricultural crops and, implicitly, human health. The unprecedented advancement of technology in all areas of human activity has both positive and negative consequences in terms of environmental pollution, ecological imbalance, and damage to natural ecosystems.

**e.** ***The competence of continuous professional training*** is generated by the continuous social evolution that requires optimizations and adaptations of specialists in various fields that must be linked to social, scientific, and technological developments. Identifying their own vocational training needs to continuously develop professional competence: people are forced to learn throughout their lives to be prepared to face the dynamics of the knowledge society. In this sense, teacher training entails the integration of initial and continuing professional training actions via specific action models. Thus, the *training* concept enabled a link between initial training and professional development activities to integrate and adapt the person.

The adaptation of the National Qualifications Framework (2015), general field of study 011 Education sciences, to European educational standards, as well as framework plans, curricula, and support materials, aim to adjust university education to a modern and current level of international requirements. In this context, the development of the National Qualifications Framework for the specialties of the general field of studies 011 Education Sciences is included, with a link to the European Qualifications Framework being required. Similarly, the curricula and Curriculum for the initial training specialties should be revised [35].

Also, the *chemist's professional competence standards* promote the following forms of training for fundamental training in understanding chemical phenomena and laws: courses, seminars, practical and laboratory works, theses, and annual projects. The emphasis on competences also includes interactive methods for training chemists. As a result, we find that the chemist's professional competence standards do not promote the methodologies for formation of the competences in question (Figure 1.8).

The definition of didactic competence according to the knowledge-capacities-attitudes formula supposes: the mobilization of an integrated ensemble of educational resources that is manifested in a didactic context of realization, belonging to some significant learning situations; has a completed character, materializing in performance products; competence is functional, having social utility in relation to the training-development of students [36].

As a result, there are several ways to approach the employment of chemists:

1. employment in enterprises and institutions of a scientific and applicative nature, in scientific, sanitary-epidemiological laboratories, in chemical and biotechnological plants, in various companies, etc.;

2. appointing chemistry instructors in the general education program;
3. employing personnel for international organizations.


Figure 1.8. Specific competences required for a chemist

The specialist can become a school chemistry teacher in the pre-university education system by mastering the psycho-pedagogical module. The specialist can be required by numerous international institutions due to his/her interdisciplinary knowledge, modern information technologies, and one or more foreign languages.

Research competence, professional communication competence, digital competence, ecological competence, and continuous professional training competency are therefore important for professional training and will help specialists in the field of chemistry integrate successfully into society.

The university professors who are responsible for the initial professional training of the students focus their educational strategy on the development of the functional competences' framework. As a result of the ideas presented in this order, we conclude:

- in the initial training programs the objective is the formation of some competences specific to the teaching profession;
- initial training involves the growth by students of a set of knowledge, capacities and basic skills for the specialty in question;
- the need to train active specialists, able to be actively involved in the learning process and to be permanently trained;
- training in the field is no longer just an initial training, here it would be necessary to transform classical education from the emphasis on initial training into lifelong learning, throughout life, moving to education focused on professional activity and individual learning.

E. Joița offers **a model of teacher training based on three dimensions from the perspective of competence pedagogy**: *the cognitive-axiological dimension*, which includes fundamental biophysical abilities and cognitive-intellectual abilities; *the motivational-attitudinal dimension*, which contains regulatory capacities related to: the affective, motivational, volitional, and value-attitudinal domains, of the orientation in the problematic; and *the action-strategic dimension*, which constitutes the third dimension [37]. Thus, ***in the process of university training of chemistry students there is a need to change the emphasis from contents to competences***, as a result, the training and development of professional competence is a continuous process that from the one hand, is made possible by the individual's ability to reorganize their knowledge and abilities into complex integrative acquisitions as they gain experience, as well as the evolution of their knowledge and abilities set. It denotes the process of becoming a professional in the chosen profession.

*General professional competences of chemistry students* aim at:
- capitalizing on the normative-regulatory framework and educational policies, from the perspective of ensuring the quality of education, demonstrating fairness/a critical spirit, and responsibility;
- designing the educational process for different target groups, based on conceptual landmarks and the approved methodological framework,

capitalizing on the inter- and transdisciplinary approach, critical and creative thinking;
- implementing the educational process with various target groups and in varied situations, demonstrating a responsible attitude towards the individuality of the subjects while using educational technologies that are suited to the accepted paradigm;
- establishing an efficient educational partnership based on the formative potential of the educational factors with openness and involvement; constructive resolution of institutional conflicts, problem situations in the educational field, showing assertiveness and tolerance;
- evaluation of the educational process by reporting to the approved normative and methodological framework, in order to make efficiency decisions;
- the management of continuous professional development, depending on the trends of the evolution of the educational practice, prove the high motivation and the professional responsibility.

*In the context of research to enhance the professional competences of chemistry students is important to strengthen decision-making competence that are reflected in*: capacity to relate to students, influencing learning behavior, capacity to influence the group and each student, planning and design ability, capacity to organize, monitor and coordinate the activity of the class / group, the correct administration of objections and approvals, balance of authority – responsibility and resistance to stressful situations.

The 0114.5 study programs oriented towards the training of teachers with specialization in various school disciplines, within the field of professional training 0114 – Teacher training, are part of the General Field of Studies 011 Education Sciences. Within these study programs, the professional training of specialists in the field of education sciences is carried out, by developing transversal, general and professional competences.

Qualification Teacher specializing in various school subjects focuses on a system of competences (knowledge, abilities, attitudes, and values) that allow students' training (altruism, humanism, creativity, responsibility, empathy, openness, and so on) while also creating a positive educational and formative environment. The previously targeted qualification's competency system necessitates theoretical knowledge and abilities in the fields of psychology, pedagogy, private teachers (psycho-pedagogical component), and theoretical knowledge and abilities in related fields, which serve as a source of educational content (mathematics, history, geography, physics, chemistry, biology, computer science).

To develop the competences system, *professional training in accordance with the chemist's professional competence standards*, for the purpose of fundamental training in understanding chemical phenomena and laws, promotes the following forms of training: courses, seminars, practical and laboratory work, which will focus on case studies, simulations, problem solving, which stimulates authentic learning in real contexts. The use of modern technologies, such as educational software, electronic platforms, and advanced educational technologies based on active and interactive methods, is also encouraged.

*The competences of digital, ecological, and investigative competence* are not adequately reflected in the National Qualifications Framework for Higher Education (CNCRM 2018), the field of professional training 0114.5 Chemistry.

Going back to the structure of professional competence, the researchers unanimously agreed that competence is an integrated functional system comprised of three elements: knowledge, capacities, and attitudes and values. We discovered that attitudes and values are not reflected in CNCRM 2018 (level 6), the field of professional training 0114.5 Chemistry.

Thus, after analyzing CNCRM-2018, we discovered that the competences required for the initial professional training of future chemists are integrated as follows (Table 1.4):

Table 1.4. Correlation of professional competences required for chemistry students with professional competences from higher education proposed in NQFRM 2018 (level 6), field of professional training 0114.5 Chemistry

| **Competence** | **Specific professional competence, NQFRM 2018** | **Knowledge** | **Capacities** | **Minimum level of recognition / evaluation** |
|---|---|---|---|---|
| Communication competence | SPC 7<br>Constructive resolution of conflicts and problem situations within the classroom, between students and their families, or within the educational institution, while demonstrating respect and tolerance. | - Conflict development factors, ways to prevent / overcome conflicts;<br>- Types and styles of communication<br>- The specifics of students' interaction in classes;<br>- The characteristics of the student class management;<br>- The psychological peculiarities of the students. | 1. Identifying conflict-generating situations;<br>2. Determining the ways to prevent / overcome conflict situations;<br>3. Classification of communication types and styles;<br>4. Analysis of the characteristics of the class of students as a social group;<br>5. Use of techniques / tools to determine the structure of the students' class. | Proposes suggestions for effective communication and solutions to overcome problem and conflict situations. |
| Continuous vocational training | SPC 9<br>Managing continuous | Trends in the evolution of educational theory and | Identifying the needs of continuous training; | Develop a professional |

| | | | | |
|---|---|---|---|---|
| competence | professional development, in accordance with the trends of the evolution of theoretical landmarks and educational practice in general and education theory and methodology in particular, showing motivation and responsibility. | practice;<br>Innovative ideas in education;<br>Ways of continuous training. | Setting priorities in professional development. | development plan. |
| Research competence | - | - | - | - |
| Digital competence | - | - | - | - |
| Ecological competence | - | - | - | - |

Thus, professional attitudes refer to the level of specialists' training to provide an observable and evaluable answer to specific problems of chemistry teaching, being the key to the desired result, which guides and motivates performance achievement. On the one hand, because attitudes are internal psychic structures, direct observation and measurement of attitudes are impossible. Attitudes, on the other hand, are manifested through behavior depending on values [38]. Correlating with the laws of society and nature, internalized attitudes become relatively stable and create favorable premises for the formation of values. D. Antoci highlights that attitudes lead to the formation of values, and the value system constitutes the context for the shaping of existing attitudes and the formation of new ones. Thus, the relationship between attitudes and values is interdependent. Values are assimilated through experience, relationships with the environment, and education, depending on society's value system and acting from the inside out [39].

There is a need to identify a new philosophical idea for modern and future pedagogy in a context where the volume of human cognitive acquisitions is increasing exponentially and there are revolutionary changes in the field of technologies. It is undeniable that it must focus on the personality's ability to generate new ideas and materials useful to society based on an innovative individual logic. This creative process is only possible in the context of fostering self-learning and continuous development throughout one's life.

Chemists' most valuable characteristics are based on their ability to quickly develop effective solutions to real-world problems. Professionals with advanced research competences can actively and productively analyze factual information, develop and select algorithms, resources, and new and more efficient technologies. This level exceeds the use of previously known technologies. The development of research competence contributes to the development of all components of the pupil's / student's personal properties.

Research competence is developed in a variety of contexts, including theoretical and experimental curricular activity, extracurricular, individual work on topics of increased interest to students, research about the bachelor's / master's thesis, and so on.

The complexity and multilaterality of the training process for research competence in chemistry necessitates the development of new training methods. The most efficient methods for developing research competence in chemistry are based on experimental activities, so it is critical that the student understands the algorithm for developing the elements of research competence in order for the faculty to carry out a complete investigative activity during the pre-university stage. Laboratory work develops the ability to observe, compare, activates the student, and develops the spirit of initiative, independence in making quick decisions, but most importantly, algorithms are developed for more complicated research based on simpler experiences.

The quality of the research competence training process in chemistry students is determined by a number of factors, the most important of which are: the value of the human potential that participates in student training; scientific research directions (value and topicality); ensuring the material base; research development strategies in the institution, and so on.

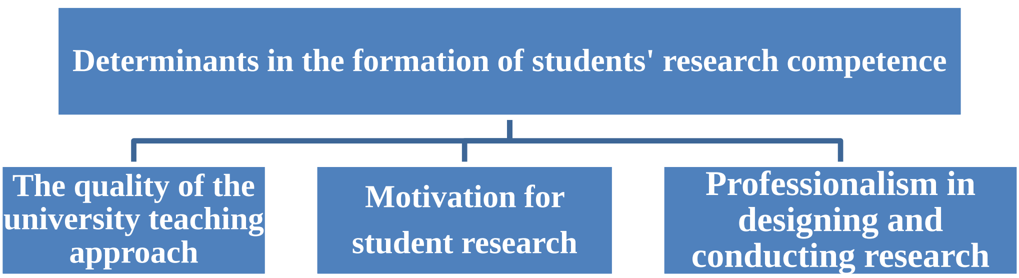


Figure 1.9. Determining factors in the formation of students' research competence

A variety of factors influence the quality of the research competence training process, including socio-cultural context, economic conditions, educational system quality (educational policies, efficiency of complex process management in the Education and Research system, quality of trainers, level of development and motivation of trainees, harmonization of the education-research-entrepreneurship relationship, and societal appreciation of e-learning).

The research activity allows the extension and consolidation of necessary professional competences in professional activity, as well as the development of intellectual capacities, which ensures the success of any activity, particularly pedagogical and investigative activities. According to this viewpoint, research competence is the universal method for solving problems in professional pedagogical activity. Developing an electronic portfolio that contributes significantly to the formation of investigative competences by developing electronic presentations, image / photo processing applications, concept mapping applications, and so on is an effective strategy for training students' research competences. By fulfilling the portfolio, it is appreciated: the innovation and originality of the works, the creativity of the product, the capacity for synthesis and analysis, the capacity for self-evaluation, and the communication competence.

At the same time, research competence is "the sum of a person's qualities, a complex capacity to objectively assess problems, to transform them into specific tasks, based on skills to conduct research" [40]. In general, we can establish that the term "research competence" is based on:

- universality – the experience gained in research during the study period will allow in the future the orientation in unknown circumstances and the solving of professional problems;
- integrativity – represents not a single unit, but a whole set of personal formations (style of activity, level of intelligence, direction of thinking, etc.);
- predictability – allows approximate prediction of results based on critical analytical thinking and formulating forecasts;
- innovation – the ability to go beyond traditional activities, to manifest creative skills, creative thinking;

- individuality – highlighting the researcher's personality, his experience in research activities and scientific interests, etc.

Research competence involves not only the capacity to assimilate new information, but also the capacity to generate new knowledge through their own activity, with a focus on personality development training processes.

A competent specialist is distinguished by the capacity to select the most optimal of many solutions, to reasonably reject false solutions, and to critically analyze effective solutions in order to understand the benefits and drawbacks of each variant under consideration. At the same time, competence involves the accumulation and constant updating of knowledge, as well as the development of novel solutions to unusual situations. A competent person must not only understand the essence of the problem, but also be able to solve it practically, using the most appropriate method for the specific circumstances. Thus, theoretical literacy, the use of efficient research methods, the ability to statistically process empirical data, formulate conclusions, and present research results are all manifestations of research competence [41].

The teacher-coordinator (trainer) must be a creative personality with initiative and autonomy in decision making to ensure the quality of the research competence training process. The development of a teacher's research competence is frequently directly proportional to his capacity to form research competence in students. It is critical for the teacher to understand the epistemological, praxiological, and axiological foundations of research, as well as to be a person dedicated to the process of knowledge development. The research objectives, the investigative process, and the values obtained as a result of the research process become an integral part of a dedicated professional's personal existence. One of the highest values of the teacher-coordinator is the capacity to guide the student towards the generation of new ideas. It is founded on intellectual abilities, professional experience, literature study, and investigative intuition. To effectively determine which of the research directions correspond to the interests and abilities of the student-researcher, the teacher-coordinator must have a variety of ideas.

The analysis of the correlation between European competences and specific competences in the Chemistry discipline, as specified in the curriculum, generates pedagogical reflections on the reality and importance of promoting research culture in the educational environment. We define research culture as the assertion of a system of convictions and rules on investigative activity, personal qualities, and investigative competences reflected in the fields: philosophical, metacognitive, heuristic, methodological, innovative, and ethical, interdependence and unity, which ensures the integrity of investigative style and dynamics optimal capitalization of investigative potential.

Table 1.5. Correspondence between research culture, key competences, and curricular specific competences in Chemistry [42]

| **European competences** (National Curriculum in Chemistry) | **Specific competences** (National Curriculum in Chemistry) | **Specific investigative competences of students** | **Fields of research culture** |
|---|---|---|---|
| **Literacy competence** (ability to create and interpret concepts) | SC 2. Characterization of chemical substances and processes while demonstrating curiosity and creativity | critical thinking and communication<br>reflective practice<br>attitudes<br>availability for development through research and innovation | **Philosophic** |
| **Mathematical competence and competence in science, technology and engineering** (explanation of natural phenomena | SC 3. Using chemistry-specific methods to solve problems, demonstrating perseverance and decision-making responsibility. | problem solving<br>explanatory scientific interpretation<br>design and implementation of research projects<br>elaboration of | **Heuristic** |

| | | | |
|---|---|---|---|
| to identify evidence and draw evidence-based conclusions) | | strategies<br>perseverance and responsibility in decision making<br>self-motivation for research | |
| **Digital competence** (critical and responsible use of ICT in contexts of learning and participation in social activities) | SC 4. Chemical substances and processes are investigated experimentally while adhering to personal and social security rules. | exploration and use of the virtual environment for distance learning<br>use of computer and resources (library and information technology)<br>identification of new information and digital sources<br>informational and investigative competences | **Methodologic** |
| **Competence of learning to learn** | SC 1. Using chemical language in a variety of communication situations while remaining fair and open to research. | informational and investigative competences<br>design and implementation of research projects<br>research engagement | **Methodologic** |
| **Civic competence** (civic responsibility) | SC 5. Harmless use of substances in daily activities, with personal responsibility for health and environmental care. | generation of research questions and conclusions<br>reorganization of internal and external resources to achieve established objectives | **Metacognitive** |

| | | | |
|---|---|---|---|
| **Entrepreneurial competence** (capitalizing of opportunities in values) | SC 3. Using chemistry-specific methods to solve problems. | initiative<br>elaboration of strategies<br>critical self-assessment<br>creativity | **Innovative** |
| **Competence in cultural awareness and expression** | SC 1. Using chemical language in a variety of communication situations while remaining fair and open to research. | availability to mobilize internal and external resources<br>research orientation<br>open collaboration | **Ethic** |

The research competence of the teacher determines the strategy of conducting the investigation, the methods and means of study applied - factors that ensure the quality of research. In the conditions of increasing the access to information, the informational competence develops abilities to relate to the informational environment, to use the new informational opportunities. Professional success increasingly depends on the ability to identify, perceive, use information productively. As a result, informational competence involves recognizing the need for information and accessing information, critically evaluating, and innovatively exploring information. Therefore, the use of information and communication technologies forms and develops the information competence, information storage and processing.

The lack of methodologies based on scientifically argued strategies is one of the major issues with organizing research training. This gap frequently has a negative impact not only on the algorithm for organizing the scientific research of the student, but also on the organization of the research process by the coordinating professors. To reduce the negative impact, activities aimed at forming the culture of scientific research within the faculty must be carried out: information courses on scientific research; familiarization with the possibilities of carrying out different researches on current scientific directions; dissemination of information about the research potential in the institution (laboratories, research centers, research equipment, etc.), as well as within the partner in crime.

Knowledge of fundamental laws and rational operation with the fundamentals of chemistry is a prerequisite for the development of field-specific competences [43]. The correlation between the level of scientific research carried out by a personality and his/her capacity to critically and rationally analyze information is studied [44].

There are three levels of training for students’ research competence in the pedagogical field [45]: basic activities are those initiated by the teacher; training-research activities are those conducted under the supervision of the teacher; and scientific research activities are those conducted independently. The basic level of training of research competence in students is characterized by: reading the reference bibliography; data analysis; determining the aims and objectives of the study; material organization; data comparison; analysis of results etc. The level of training-research of the formation of research competence in students is characterized by: formulating a hypothesis; conducting a search experiment; comparative study of some phenomena / materials; theoretical substantiation of the choice of methods; using computer tools to solve the problem; presentation of the result etc. The level of scientific research in the formation of research competence in students is characterized by problem formulation; theoretical substantiation of method selection; problem solving methods; hypothesis specification; use of research methods in related sciences; correct, logical, clear, and reasoned description of the activity process; clear formulation of conclusions in correlation with the proposed objectives; evaluation of study results.

## 1.4. CONTEMPORARY INTERDISCIPLINARY APPROACHES TO CHEMISTRY RESEARCH TRAINING FOR THE DEVELOPMENT OF INNOVATIVE THINKING

The praxiological approach of modern university education explores didactic strategies focused on action, surgery, and based on the promotion of interactive methods that require thinking, intelligence, imagination, and creativity mechanisms. Cognitive activity is based not only on the assimilation of existing information, but also on analysis and synthesis, as well as the formation of individual conceptions about the world around us. The most productive form of knowledge is research activity, which is an essential component of the university educational process.

The identification of vocational education with the principle of inter- and transdisciplinarity gives the curriculum a flexible character, responding to another fundamental principle of modern education, the positive change of pedagogical professionalism. Alternatively, curriculum revision is an immanent action of both the university education process and education in general. Curriculum renewal, also known as curricular development, is carried out in accordance with certain principles. This entails changes to the concept, structure, and contents of the curriculum components in accordance with the imperatives of educational practice and suggestions from educational sciences research. In fact, any curriculum developed in a university setting will be conceived of as a tool to change things for the better.

The valorization of the principle of inter- and transdisciplinarity in the design of university teaching strategies for research training is a complex activity on the part of the teacher which involves, first of all, the selection, organization / combination of teaching methods in relation to the predicted objectives / purposes: the way of approaching the learning, the forms of organization of the teaching-learning-evaluation process, the didactic guides, the time necessary for the application of the chosen didactic strategies. Teaching strategies can be approached and defined from several perspectives, which complement each other: as an integrative approach and action, as a procedural structure and combination of pedagogical decisions, etc.

Table 1.6. University teaching strategies and directions of pedagogical action in research training

| Directions for pedagogical action in research training | Teaching strategies |
|---|---|
| 1. Conceptualization of research<br>2. Carrying out chemical investigation<br>3. Assessment of the impact of chemical investigations | Learning problematization strategies<br>Expository strategies<br>Heuristic strategies<br>Algorithmic strategies<br>Illustrative-explanatory teaching strategies<br>Cooperative learning strategies<br>Strategies focused on research action<br>Problematized strategies |

Individual activities, group activities, activities in pairs, and mixed activities are all forms of organizing the educational process that must be considered when designing teaching strategies. Currently, professional occupations require specialists who can not only possess knowledge, but also create new knowledge and adapt some knowledge in conditions that differ from the theoretical ones. For these reasons, higher education institutions' role is to prepare graduates to deal with real-world problems by analytically reconfiguring available knowledge and intuitively forecasting final outcomes.

Students in universities participate in a variety of research activities, which can be broadly classified as either research activity that falls within the educational process or research activity that exceeds the limits of the curriculum. The choice of activities within the curriculum that go beyond the curriculum is determined by the student's personal interests and abilities. The goal of research is to obtain new scientific knowledge, or a new objective result. This type of activity is only available to a small number of students because acquiring knowledge that is truly new to science during a university period of study requires a specific research infrastructure and resources, which are extremely rare, but the efficiency of the professional development process can be quite high because it is based on a strong intrinsic motivation. Involving research teams in financed projects can be an effective solution.

The purpose of research training is not only to produce fundamentally new scientific results, but also to develop research competence that can serve as a springboard for new ideas and research. One important objective is to develop an analytical thinking style based on scientific research laws.

In the field of chemistry, it is critical that research and innovation play a significant role in the process of developing professional competence. These are factors that directly favor the transfer of theoretical knowledge to practical applications, as well as the development of new materials and innovative technologies based on applied knowledge and individual creativity. It is crucial that students participate in the synthesis and qualitative analysis of chemical compounds, as well as determine the potentially useful areas for their application, as well as the economic and ecological impact for complex analysis, in order to make an informed decision about whether these studies are worthwhile. If so, in what proportions.

Almost two decades ago, studies at Finnish universities revealed that not only researchers, but also students, require basic research skills and scientific thinking in order to integrate into the labor market and act as an active knowledge builder in society [46]. Of course, this competence is formed over time, beginning with school, so it is critical that students understand the significance of this process and are motivated to develop using this methodology. To engage them in this constructivist activity, they must solve practical utility problems in order to be convinced of the value of this competence for life and professional activity. Parallel studies have revealed that students in Finland and the United States have different perspectives on research competence, which can be explained by the two education systems' different perspectives on the importance of each personality in an innovative knowledge society.

The development of research competence is important from an educational standpoint for the individual development of the student's personality, because it allows for the creation of one's own system of ideas, activities, and conclusions, as well as a change in attitude toward society and the educational process at the university. This process allows for a complex synthesis of theoretical and practical knowledge, but most importantly, it emphasizes knowledge actively acquired personally through investigations. All at the same, with experience, such qualities as professional intuition develop, allowing the prediction of goals of ongoing activities and allowing decisions to be made to achieve the intended goal.

The institutional management of research activities in the field is an important factor in promoting the research culture. Forecast models are described for improving management in research institutions based on strategic development plans that promote a culture of research and innovation [47].

Implementing pedagogical innovations and new technologies based on advanced scientific advances is critical for promoting research training and innovation transfer. It has been established [48] that there are a number of impediments in higher education institutions: a lack of infrastructure that would appropriately promote innovation, a lack of motivation mechanisms for innovative activity, an unsatisfactory technical and material basis, poor team information on innovative activity, the belief that the traditional training style is efficient, a large share of auditing hours, a lack of experience with innovative activity, and a fear of negative outcomes. We identify the main necessary conditions for innovative activities for the development of research competence [49, 50]:

- prospective vision – the ability to forecast realities and needs in the near future in the field;
- ability to make innovative decisions;
- the courage to take certain risks;
- the ability to adapt in the process of practical implementation in real conditions, etc.

The needs of developing the branches of the economy through efficient solutions that are qualitatively superior to existing analogues dictate the development and implementation of innovations. Recently, a number of new terms have emerged in universities, based on the need to focus on research-innovation: innovative education, innovative technologies, innovative transfer, innovative university, innovative potential of the university, innovative forecast, innovative project, innovative incubator, process innovative, and so on [51-53].

University excellence will become a reality in circumstances where there are visible openings for a change in perception of higher education in postmodern society, capacities to exercise the functions imposed by contemporary challenges are strengthened, and, of course, individual and creative attitudes are supported. Beginning with the notion that efficiency is a human characteristic, students must demonstrate the following in order to be effective in research:

- motivation for research, development and innovation;
- personal integrity;
- rationality and economy;
- clarity of the research purpose;
- adaptation to change;
- opening to the new;
- consistency in decisions;
- self-management and research initiatives;
- high level of participation and professional integration;
- maximum focus on self-directed learning;
- deep motivation for independent learning;
- willpower and rational use of time;
- creativity and energy;
- learning priorities;
- synergy and scientific productivity.

The participatory nature of university courses and seminars can be ensured by stimulating students' discussions and opinions, as well as by requesting as many explanations, arguments, theoretical-applied examples as possible that are not presented during the course.

According to this viewpoint, the scientific research activity aims to train students in scientific research competences in the field of professional training, while also encouraging options for scientific careers in the field. The general goals of students' scientific research activity are as follows: the orientation of the students in the issue of immediate and perspective scientific research; guiding documentation and information in the literature; initiation in research technique and mastering the scientific research methodology; capitalizing on the potential of scientific and technical creativity of students through symposia, communication sessions and the formation of epistemic attitudes, research and scientific research.

University teachers will lead the pedagogical approach to the development of students' innovative thinking, which means a creative process of professional thinking in which students assert themselves through their ability to provide innovative solutions to life problems, from the perspective of training students in research competence. Professionalism, critical thinking, and novel scientific findings inductive and deductive reasoning are used by innovative teachers to synthesize information and make productive connections of new ideas, curiosity, and collaboration. The originality of the ideas that are launched is a necessary characteristic of innovative thinking.

The constant stimulation of students' scientific curiosity through effective management of individual study and independent learning activity generates motivation in students to create new knowledge. The distinctiveness of innovative thinking is found in its assertion in professional activity via explicit reasons for autonomous learning and professional development via complex involvement in research with obvious scientific productivity. The innovative professional thinking style is expressed in the innovative activity, which emphasizes the originality of the scientific discourse as reflected in the complexity of approaching the research issue.

The effectiveness of university teaching entails: contributing to the success of education and student progress, training students in cognitive strategies for information development, and producing new knowledge. The study of learning activity and student performance revealed the difficult field of effective student learning: underemployment or insufficient employment of students – below the optimal limit of achievement of general and professional skills, which causes failure; difficulties in managing teaching and personal time, learning conditions; establishing the most appropriate learning methods and techniques for the categories of university objectives, for the learning stages, solving tasks; training motivation for learning in students; disinterest in scientific research of students; superficial integration of students in professional practice, etc.

According to this viewpoint, innovative thinking manifests itself in the theoretical-scientific and creative approach, which is constructive and pragmatic, with a high potential for content and scientific significance renovation. Innovative thinking is the result of research training that is geared toward the development of new scientific values. The constructive nature of students' innovative thinking is manifested by their capacity to diagnose and predict educational changes, as well as their capacity to objectively evaluate the quality of the learning process and research style in professional education. The innovative thinking of university teachers, which stimulates the affirmation of research and innovation competences, theoretical-practical creativity that can generate processes of positive change in professional activity, the main feature of innovative thinking is the pragmatic orientation of research. To summarize, in order to ensure the development of research competences and the expression of innovative thinking in the university environment, it is necessary to develop students' personal qualities that stimulate the development of research culture: initiative, logic, and perseverance, inspiration and motivation for research, research productivity, and its socioeconomic value. [54, 55].

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# CHAPTER 2. THE CONTEXT OF PROFESSIONAL FORMATION OF RESEARCH COMPETENCE AT CHEMISTRY STUDENTS

Chemistry is distinguished by the specificity and necessity of applying experimental activities, which allow the valorizing of theoretical acquisitions, the formation of fundamental concepts about the phenomena of the surrounding world, as well as the discovery of new aspects of the studied compounds and/or processes. Since chemistry is a branch of natural and exact sciences, research methods based on the principle of interdisciplinarity are frequently used in practical activities: laws from physics and biology, mathematical calculations, physical methods of analyzing chemical compounds, and so on. To enhance a research culture among the students, it is critical to create an evolving algorithm based on age-specific characteristics, employing complex training forms and methods. Interdisciplinary studies allow for a multilateral approach to the phenomena being studied, the application of new methods from related fields to elucidate some specific aspects, which can open new research directions, and the opportunity for practical application of the acquired knowledge. The purpose of current chemistry didactic strategies is to focus the training process on investigation in order to form the research competence required for future specialists to develop new ideas based on their own visions. The following stage is the formation of abilities to develop technologies based on novel ideas – a level of research culture that lays the groundwork for the emergence of new advanced materials and high-performance technologies.

## 2.1. DETERMINANTS OF THE FORMATION OF RESEARCH COMPETENCE AT CHEMISTRY STUDENTS

The conceptual and methodological concerns of university teachers regarding the professional training of students' investigative competence are regarded as a strategic objective for the higher education system, remaining a determining factor of academic success, and are reflected in students' participation in independent research activities as one of the most productive forms of creative activity through cooperation.

The national higher education system significantly improves its directions and level of training of competitive specialists in the field of Chemistry in accordance with the provisions of the Bologna Agreement. The university system provides a platform for young people to deepen their knowledge in their field of specialization. To ensure the continuity of competences training, the university system must coordinate vocational training policies not only with the graduate employment sector, but also with the pre-university education system. The training of future chemists is intended to instill in students the ability to achieve an interdisciplinary approach to chemistry with biology, physics, computer science, and mathematics [1]. The study of a set of interconnected chemistry disciplines contributes to the development of various mechanisms, tools, and procedures for the formation of professional competence of the future chemist.

In practice, ensuring the conditions for the integrated study of chemistry with other disciplines leads to successful information assimilation in both the field of chemistry and other academic disciplines. The Chemistry discipline at university includes an integrated system of knowledge specific to the field, but also to related disciplines, acquired efficiently and consciously, ensuring fundamental competences in professional activities.

Because science is constantly evolving, the processes that ensure the connection between the fields of education-research-professional activity must be constantly adapted. It is effective to rely on the paradigms that govern their development in order to systematize and monitor these processes. A paradigm is a logical and orderly framework of accepted ideas and principles by a scientific community that provides a general explanation of a pedagogical phenomenon. Each paradigm involves structuring a particular conception of the world and life, which is more or less distinct from the viewpoint from which other paradigms address the same issue (Figure 2.1) [2].

*The axiological paradigm* assumes objective phenomenology of the development of values between the two poles: positive and negative, truth to false, and so on, with all possible modulations and oscillations in the axiological interval. According to H. Rickert [3], the systematization of values must be open to cultural development. The chemistry student's value orientations represent a unit of interconnected values that guide learning and individual activity. Value orientations are reflections, i.e., values are reflected in the individual's consciousness as priority purposes of professional life, but also as indicators. They are created dynamically and actively in the student's personality through learning. Values can be seen in cognitive, affective, and behavioral terms, but it can also be seen in interpersonal relationships, individual-nature relationships, the Self, and so on. The axiological paradigm aims at scientific contents as truth principles that shape the formation of the chemist student's professional competence.

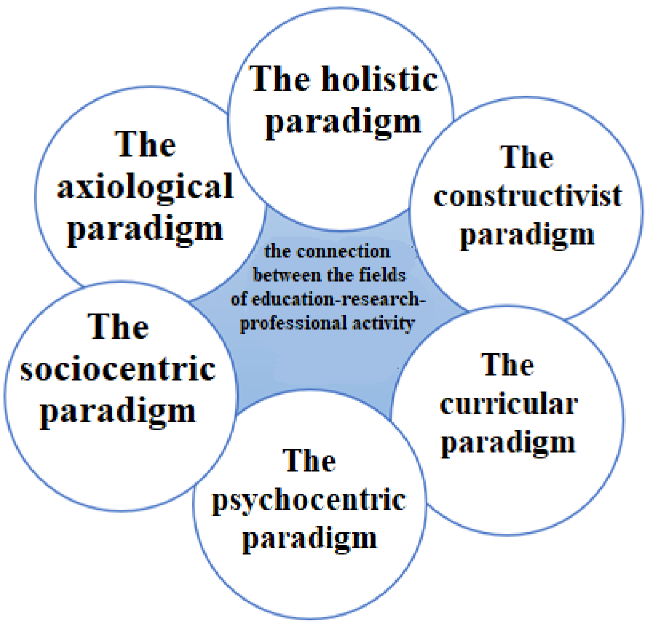


Figure 2.1. The paradigmatic approach of the connection of the fields: education-research-professional activity

*The holistic paradigm* is especially important in approaching professional competence, which is determined by the evolution of integrated scientific knowledge unique to modern human thinking. Holism is a principle of connection and mutual determination of natural and social phenomena, as well as the procedural significance in the formation of an organized complexity, in the context of training the professional competence of chemists. At the same time, the holistic approach to professional competence formation represents intrinsic integrity because the personality attempts to achieve specific objectives in professional activity.

*The constructivist paradigm* emphasizes the learning process and how it is accomplished, because what matters in learning is not *what* and *how much you learn*, but *how you learn*. Students in chemistry gain learning experiences that involve them in developing hypotheses, conducting research, asking questions, predicting, and not simply assimilating transmitted knowledge. As a result, cognitive mental processes are crucial in constructivist learning. Students face cognitive conflicts, reflect on problems, formulate hypotheses, and so on because of constructive learning. The priority in constructivist knowledge is not acquiring as much knowledge as possible, but rather how it is aware, identified, constructed, and interpreted.

M.-D. Bocoş [4] thinks that knowledge construction entails the subject being informed, seeking, selecting, critically treating information regardless of its source, reformulating, analyzing, comparing, building action strategies adapted to his own training and personality, classifying, evaluating, formulating hypotheses, testing them, experimenting, discovering, concluding, and so on. As a result, students can personalize their activities and develop their professional competences. The constructivist paradigm serves as the foundation for the methodology used to train chemistry students' professional competences.

*The curricular paradigm* is a complex and coherent set of legal aspects that guides the pedagogical approach of a learning action at various levels of operationalization. The curriculum is an educational activity program that includes curricula, school curricula, textbooks, and methodological guides [5].

*The psychocentric paradigm* emphasizes the fact that pedagogy is primarily concerned with the psychological needs of education and the educated [6].

*The curricular paradigm* for education is being developed in response to the need to resolve conflicts between the psychocentric and sociocentric approaches to education, as well as between teacher and student (Table 2.1).

Table 2.1. Characteristics of the psychocentric and sociocentric approach

| **The psychocentric approach** | **The sociocentric approach** |
|---|---|
| ❖ *focuses on the student, is oriented toward the concept of whole-person development and promotes learning through activities in which the student voluntarily engages in his choice, in spontaneous exploration, and play.*<br>The educational system provides the following characteristics based on the psychocentric approach:<br>• education focused on the educated, on his natural, physiological and psychological qualities;<br>• knowledge of the student's psychological resources, based on observation methods;<br>• carrying out effective practical actions in the natural pedagogical environment; | ❖ *aims at the direct influence of adults (parents/educators) on students through attitude, verbal message, gesture, emotional state, personality example, and so on, or by their active and indirect presence, through other educational factors (family relatives, social group, community).*<br>The teacher guides, manages / organizes, monitors, and evaluates the student's activity in the educational institution; it maintains its role as a facilitator. Interactions among colleagues and group work are thus encouraged, and symbolic play, or so-called play, is regarded as equally important as cultural learning. Adults' roles include arranging the playground, determining what equipment is used for play and other activities, and |

| | |
|---|---|
| • respecting the student's freedom of expression;<br>• organizing the content of education in relation to the functional requirements and interests of the student;<br>• institutionalization of the child (at the decision of the parents);<br>• individualization of education by capitalizing on all the resources of the child's multiple intelligences. | organizing the program for their development, as well as approaching children in a way that encourages cultural learning.<br>Teachers guide and support children during their social and intellectual development. |

*The sociocentric paradigm* focuses on the fact that pedagogy is focused primarily on the requirements of society (civic, cultural, political, economic, etc.) towards education and educating [6]. Curriculum development at the postmodern stage focuses on the diversity and interaction of different curricular approaches and concepts: (a) holistic curriculum design; (b) the design of the student-centered curriculum; (c) the design of the integrated curriculum; (d) the design of the competency-based curriculum.

The development of creative thinking has become a common theme in modern education. Students' creativity strengthens their professional capacities and improves their intellectual activity tools. The success of the didactic strategy is determined by the universities' knowledge of interactive methods, technological flexibility, and ability to combine them while efficiently utilizing educational means.

The specificity of the educational paradigm influences the chemistry student's set of theoretical values (Table 2.2), which reflects the values of research competence formed within different educational paradigms [7].

Table 2.2. Theoretical values formed within different educational paradigms

| Paradigm | Theoretical values |
|---|---|
| axiological | ✓ the value orientations of the chemistry student are the part of interconnected values system, which direct the learning process;<br>✓ values represent reflections, i.e., in the consciousness of the chemistry student they are reflected as priority purposes of the professional activity, but also as indicators and they are built dynamically through learning in their personality;<br>✓ the values can be manifested cognitively, emotionally and behaviorally, but also in the field of interpersonal relationships, in the field of individual-nature relationships;<br>✓ aims at the scientific contents as values of truth that underlie the formation of the professional competence of the chemist student;<br>✓ integrated scientific contents – values formed through university education;<br>✓ has significance in approaching the professional competence, which determines the evolution of the integrated scientific knowledge specific to modern human thinking;<br>✓ considers that the physico-chemical phenomena are dependent on the biological ones, analyzing the whole in order to reach its components. |
| holistic | ✓ allows the investigation to identify new aspects of the phenomenon of professional competence of chemistry students;<br>✓ can offer a new research direction related to the issue of training professional competences;<br>✓ represents an intrinsic integrity since the personality aims to achieve a purpose in professional activity. |
| constructivist | ✓ highlights the learning process and how it is done, being important in learning not what and how much you learn, but how you learn;<br>✓ chemistry students gain learning experiences that involve them in formulating hypotheses, to research, to ask questions, to predict and not to assimilate transmitted knowledge; |

| | |
|---|---|
| | ✓ an important role in constructivist learning is played by cognitive mental processes, where students face cognitive conflicts, reflect on problems, formulate hypotheses, etc.;<br>✓ priority in constructivist knowledge is not the acquisition of as much knowledge as possible, but the fact how they are aware, identified, constructed, interpreted;<br>✓ knowledge construction means that the subject is informed, seeks, selects, critically treats information regardless of their source, reformulates, analyzes, compares, classifies, evaluates, formulates hypotheses, tests them, experiments, discovers, makes conclusions;<br>✓ the student personalizes his work methods and builds his action strategies adapted to his own training and his own personality, thus developing the professional competence;<br>✓ is the basis of the methodology for training the professional competence of chemistry students. |
| curricular | ✓ the curriculum is a program of educational activity that is concentrated in the curriculum, school programs, textbooks, and methodological guides due to its integrity and functionality. |
| psychocentric | ✓ pedagogy is primarily concerned with the psychological requirements of education and the educated. |
| sociocentrist | ✓ pedagogy focuses on the needs of society (civic, cultural, political, economic, and so on) in terms of education and being educated, by educating an individual who can integrate both socially and professionally. |

The Republic of Moldova signed the Bologna Declaration in May 2005, becoming a part of the Bologna Process, which aims to create a common European space for higher education and research. One of the key goals of the Bologna Process is to implement curricula that are transparent, student-centered, and purpose oriented. The Republic of Moldova's accession to the Bologna Process provided the opportunity to initiate reforms in the field of university curriculum, including: organizing flexible and modularized study programs; implementing new technologies; reorganizing initial training programs for future teachers;

and organizing student study activities focused on the formation of general competences (transferable and adaptable depending on the chosen field of activity) and specific, with the help of which the student will be able to integrate more easily on the labor market [8].

The competence-centered curriculum is currently the most popular international trend in the field of curriculum theories. In general, this trend promotes the procedural model of learning and aims to adapt learning to how cognition receives, processes, and uses information. Learning is thought to become simpler, take less time, and be more efficient this way. Each higher education institution has the right and responsibility to develop a curriculum that is personalized to its own curricula strategies under university autonomy [9].

The university curriculum is planned and implemented in accordance with the autonomous status of universities and departments, and each professor has the right to his or her own didactic vision. In this sense, even within a faculty or department, management of the design and implementation of the written curriculum is not hierarchical. As a result, the design and implementation of some curricula may differ from the design and implementation of others.

We deduce attitudes and values from the specific competences proposed in the research that are required for chemist training (Table 2.3).

Table 2.3. Attitudes and values of the chemistry student

| Competence | Attitudes and values |
| --- | --- |
| *Research* | ✓ critical appreciation and curiosity towards the research fields;<br>✓ interest for the development of research directions;<br>✓ attitude and respect for security and sustainable development;<br>✓ application of research results with impact on family, society, and global issues. |
| *Professional communication* | ✓ positive attitude for constructive dialogue;<br>✓ appreciation of aesthetic qualities / values and desire to promote them;<br>✓ interest in communicating (interacting) with others;<br>✓ awareness of the impact of language on others;<br>✓ the need to understand and use chemical language in a scientific and responsible way;<br>✓ moral responsibility for the state of the environment;<br>✓ critical and reflective attitude towards the available information;<br>✓ responsible use of information sources and interactive means. |
| *Digital* | ✓ interest in involvement in communities and social networks for cultural, social and / or professional purposes;<br>✓ emotional attitude towards nature, as love towards nature. |
| *Ecological* | ✓ norms of behavior towards nature;<br>✓ the possibility and consequences of changing the attitude towards nature;<br>✓ reflection on the place and role of man in the biological and physical world. |
| *Continuing vocational training* | ✓ motivation and confidence for lifelong learning;<br>✓ responsible attitude focused on solving the problems of one's own learning process and the ability to remove obstacles and manage change;<br>✓ manifestation of desire in the exploitation and use of learning experiences. |

We deduce the system of attitudes and values by analyzing National Qualifications Framework in the Republic of Moldova (2018) in relation to general professional competences:

- capitalizing on the inter- and transdisciplinary approach;
- capitalizing on critical and creative thinking;
- creative use of modern and specific educational technologies;

- manifesting the responsible attitude towards discipline and towards the individuality of the subjects;
- making the reverse connection in the educational process;
- creating an effective educational partnership, demonstrating openness and involvement;
- constructive conflict resolution showing assertiveness and tolerance;
- making decisions to streamline the educational process;
- awareness of continuous professional development, showing motivation and responsibility.

## 2.2. ENSURING THE INTERDISCIPLINARY NATURE OF THE COURSES IN THE TRAINING PROCESS OF CHEMISTS

Chemistry training would be impossible without the application of knowledge from biology, physics, and other disciplines with which it has numerous tangents. Because matter is made up of substances, sciences like biology, physics, and geology study chemical compounds and the phenomena that are influenced by their properties. Chemistry, in turn, makes extensive use of knowledge gained from neighboring sciences to explain the composition and structure of substances, as well as the nature of chemical phenomena, more convincingly (Table 2.4).

Through the use of interdisciplinary studies, the level of efficiency of Chemistry training can be increased. Analyzing the study programs of the specialties proposed within the Faculty of Biology and Chemistry of TSU, it is found that there are interdisciplinary courses that appeared at the interpenetration of chemistry with other disciplines even at the university training stage [10].

Curricula may include the following interdisciplinary disciplines, depending on the specialty: Biological chemistry, Physical chemistry, Electrochemistry, Hydrochemistry, Ecology, Crystallochemistry, Radiochemistry, Ecological chemistry, Food chemistry, Physico-chemical methods of analysis, Applied information technologies in Chemistry, Nuclear Chemistry, Hydrobiology, Astrophysics, Agrochemistry, Plant Ecophysiology, Ecogeography, Psychophysiology, and other fields.

Table 2.4. Content of interdisciplinary courses within the specialties of the Faculty of Biology and Chemistry of TSU

| **Speciality** | **Disciplines (total), no.** | **Interdisciplinary disciplines, no.** | **Content of interdisciplinary courses, %** |
|---|---|---|---|
| Biology and chemistry (full-time) | 87 | 7 | 8.05 |
| Chemistry and biology (full-time) | 78 | 8 | 10.3 |
| Chemistry and physics (full-time) | 85 | 7 | 8.24 |
| Biology (full-time) | 56 | 5 | 8.93 |
| Ecology (full-time) | 55 | 7 | 12.73 |
| Chemistry (full-time) | 61 | 7 | 11.48 |
| Biology (part-time) | 70 | 8 | 11.43 |
| Chemistry (part-time) | 65 | 7 | 10.77 |

Based on the results (Table 2.4, Figure 2.2), we can see that the share of interdisciplinary courses is between 8.05 and 12.73 % almost in all specialties of the Faculty of Biology and Chemistry at TSU.

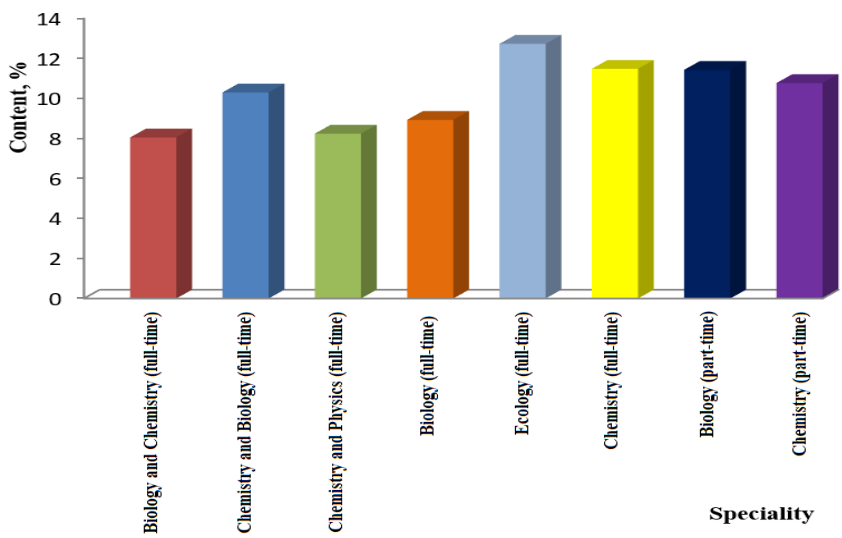


Figure 2.2. Content of interdisciplinary courses

The highest degree of interdisciplinarity (12.73%) was attested in the specialty of Ecology (full-time), because the study of ecology leads to the formation of an education, ecological awareness that is based on the development of specific competences and contents in an inter/transdisciplinary vision and accessible to students, the transition from systemic-fundamental knowledge to functional knowledge, problem-solving and application of specific competences (acquired in other disciplines) to investigate and solve environmental problems, on interdisciplinary integration, which in turn involves all components the instructive-educational process (competences, contents, learning activities) and uses the uniqueness of the common scientific knowledge in the initial professional training of the student.

In the first cycle of the TSU, Faculty of Biology and Chemistry, there are two training areas: Exact sciences for full-time students and Education sciences for full-time and part-time students. However, in both cases, the content of interdisciplinary courses is around 11%. Hydrochemistry, Crystallochemistry, Physical Chemistry, Biological Chemistry, Radiochemistry, Ecological Chemistry, and other courses from these two fields make interdisciplinary connections. Undergraduate theses in these specialties are also interdisciplinary in nature.

The interdisciplinary approach is the most appropriate level of integration for chemists' professional competence training. A number of problems related to student training, development, and education can be solved through interdisciplinarity, as can an integrated approach to solving reality's complex problems. A fundamental issue with university-level training in exact sciences is an insufficient interdisciplinary approach of phenomena in the fields of biology, chemistry, and physics. Although the legalities within these disciplines are the basis of most processes related to human activity or other fields (physiological processes, exchange of substances, the circuit of matter in nature, the transformation of energy from one form to another, relationships in food chains, etc.), their fragmented teaching makes these specialties (especially chemistry and physics) less known fields.

The contents of the initial training programs include scientific arguments in this regard, such as quantum-chemical calculations, coordinating compounds, and so on. As a result, initial vocational education should be oriented toward the development of vocational competence through interdisciplinary integrated content.

According to the Curriculum in Higher Education [10], curricula are divided into two parts: compulsory and optional. An optional curriculum can be: in-depth, extensive, innovative, or integrative, depending on the content. Optional integrated curriculum aims to introduce a new discipline of study, structured around an integrative theme for a curricular area or several curricular areas, to develop new competences and new contents [ibidem, p. 13].

We advocate an optional integrated curriculum, called interdisciplinary, that involves an organization that goes through all disciplines to focus comprehensively on life issues or broader areas of study, which bring together various segments of the curriculum to achieve meaningful associations, based on the idea that a quality education would aim to train future specialists in a systemic, integrative thinking, a holistic view of life.

It was proposed to develop the interdisciplinary curriculum *Chemistry for Life – Integrated Research* in the context of approaches regarding the initial professional training of the chemist student in order to rationalize and streamline the teaching-learning-evaluation process.

The purpose of the interdisciplinary curriculum is to train chemistry students' professional competence by acquiring specific competences, developing analytical capacities and integrated thinking, and personal expression abilities in debating ideas, as well as cultivating a tolerant attitude toward the environment.

The curriculum was designed as a "free choice" for knowledge extension and deepening, as well as integrated training-assessment activities, and was designed within the specialties of Chemistry, Chemistry and Biology, and Biology and Chemistry. Furthermore, the curriculum presumes the development of competences required for vocational training: Investigative competence, Professional communication competence, Digital competence, Ecological competence, and Continuing professional competence, all of which are critical in the context of social integration, but also in training chemistry students to develop their own career project.

The integrated contents were designed based on an analysis of the courses studied by students from Chemistry (full-time education), Chemistry and Biology (full-time education), Biology and Chemistry (full-time education), and Chemistry (part-time education) at the faculty of Biology and Chemistry, TSU [11].

The share of courses for professional training of chemistry students in specialties was analyzed (Table 2.5).

The interdisciplinary curriculum is organized in four modules based on the progressive evolution of knowledge: synthesis of compounds with useful properties for agriculture and industry → the study of the composition of new compounds, molecular structure, and chemical, physical, biological properties, etc. → computer modeling of molecules and chemical processes to predict the probability of processes → analysis of environmental quality.

Table 2.5. The share of training courses

| Speciality | Form of training | Course names | Term | No., lecture / laboratory hours |
|---|---|---|---|---|
| Chemistry | full-time | techniques of chemical synthesis | VI | 27/47 |
| | | physico-chemical methods of analysis | III | 15/30 |
| | | information technologies applied in chemistry | II | 15/30 |
| | | computational modeling in chemistry | VIII | 30/15/30 |
| | | ecological chemistry | IV | 45/30 |
| Chemistry and biology | full-time | techniques of chemical synthesis | VI | 24/60 |
| | | physico-chemical methods of analysis | III | 15/45 |

| | | | | |
|---|---|---|---|---|
| | | information technologies applied in chemistry | IV | 15/45 |
| | | computational modeling in chemistry | VII | 27/9/27 |
| | | ecological chemistry | VI | 45/30 |
| Biology and chemistry | full-time | techniques of chemical synthesis | VI | 36/72 |
| | | physico-chemical methods of analysis | VIII | 26/39 |
| | | information technologies applied in chemistry | - | - |
| | | computational modeling in chemistry | - | - |
| | | ecological chemistry | - | - |
| Chemistry | part-time | techniques of chemical synthesis | - | - |
| | | physico-chemical methods of analysis | I | 8/20 |
| | | information technologies applied in chemistry | II | 8/16 |
| | | computational modeling in chemistry | VII | 10/20 |
| | | ecological chemistry | VI | 20/20 |

The concept of free choice discipline is based on the concept of logical progression from the acquisition and study of chemical compounds to the protection of the environment from pollutants.

According to the ideas expressed so far, the competences required for the interdisciplinary discipline are research competence, professional communication competence, digital competence, ecological competence, and continuous professional training competence. The impact of university disciplines can be found in what they share with other study programs, which are generalizable and transferable. To summarize, the organization of information in an integrated system will demonstrate efficiency in training chemistry students' professional competence.

## 2.3. STIMULATING CURRICULAR AND EXTRACURRICULAR ACTIVITIES IN THE FORMATION OF RESEARCH COMPETENCE OF CHEMICAL STUDENTS

Increased agro-food productivity, the development of new pharmaceutical products, oenology, and other related issues are critical to societal development. The presence of several components that have a positive impact on some biological processes opens new possibilities for their use as biostimulators in microorganisms (fungi, algae) and higher crop plants [12].

Students from the first and second cycles of the Tiraspol State University submit the bachelor's/thesis master's as the finality of the study programs, obtaining the bachelor's or master's qualification depending on the specialization, as a form of competences evaluation. According to the programs, students participate in the following practical internships during their studies: Initiation Practice, Production Practice, and Bachelor's Practice [10].

During these internships, students form certain competences related to the analysis and synthesis of bibliographic sources in the established field, as well as knowledge and practical skills in the use of tableware, reagents, and some instrumental methods of analysis, which they will use in the elaboration and defense of their bachelor's or master's thesis.

The synthesis of chemical compounds, in particular – obtaining new compounds with useful properties for various fields – is essential competences for future chemists. In addition to all the practical activities included in the study plan, in which students practice the abilities of reproducing some general chemical reactions, students have a series of courses such as Chemical Synthesis Techniques, Chemistry of Coordination Compounds, and so on, in which syntheses of inorganic, organic, and coordinating compounds are carried out [13].

The proportion of undergraduate theses in the field of coordination compound synthesis varies by year, reaching more than 60% (full-time education, 2014 and 2016) and up to 20% (part-time education, 2015). The lower number of applicants from studies in the low-frequency section can be attributed to the experimental nature of field research, which necessitates physical presence and continuous investigations over an extended period (Table 2.6, Figure 2.3).

The share of master's theses completed in the field in the second cycle programs reaches up to 40% in some years (2014) and is lower compared to the first cycle (full-time education), because students from the *Contemporary chemistry and educational technologies* program work as teaching staff, and students from the *Ecological chemistry* program work in the field of environmental protection (Figure 2.3).

Table 2.6. Number of theses defended in cycle I and cycle II with thematic aiming at the synthesis of some coordinating compounds

| **Years** | **Bachelor** (full-time) • Chemistry • Chemistry and biology • Chemistry and physics • Biology and chemistry | | | **Bachelor** (part-time) • Chemistry | | | **Master** • Contemporary chemistry and educational technologies • Ecological chemistry | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total theses, no. | on chemical synthesis, no. | Share, % | Total theses, no. | on chemical synthesis, no. | Share, % | Total theses, no. | on chemical synthesis, no. | Share, % |
| 2013 | 25 | 5 | 20.0 | 36 | 3 | 8.33 | 13 | 2 | 15.38 |
| 2014 | 9 | 6 | 66.67 | 26 | 4 | 15.38 | 19 | 8 | 42.11 |
| 2015 | 20 | 4 | 20.0 | 20 | 4 | 20.0 | 23 | 4 | 17.39 |
| 2016 | 6 | 4 | 66.67 | 18 | 1 | 5.56 | 24 | 2 | 8.33 |
| 2017 | 8 | 1 | 12.5 | 17 | 0 | 0 | 17 | 0 | 0 |
| 2018 | 5 | 1 | 20.0 | 7 | 1 | 14.29 | 14 | 1 | 7.14 |
| 2019 | 21 | 9 | 42.8 | 13 | 0 | 0 | 17 | 3 | 17.6 |
| 2020 | 11 | 4 | 36.4 | 14 | 2 | 14.3 | 22 | 3 | 13.6 |
| 2021 | 10 | 3 | 30.0 | 6 | 0 | 0 | 21 | 4 | 19.05 |
| 2022 | 15 | 3 | 20.0 | 5 | 0 | 0 | 17 | 1 | 5.9 |

One of the major tasks of modern pedagogy is to create effective mechanisms for integrating training and research through the use of information technologies and field knowledge based on the needs of tomorrow's citizens.

This task necessitates extensive inter- and transdisciplinary collaboration. Chemistry has obvious ties with Physics, Biology, and Ecology, but recently, due to the dynamic development of information technologies and their implementation in various fields, including research and training, there has been a need to develop different strategies for developing students' competence in using specialized information technologies in the field of chemistry.

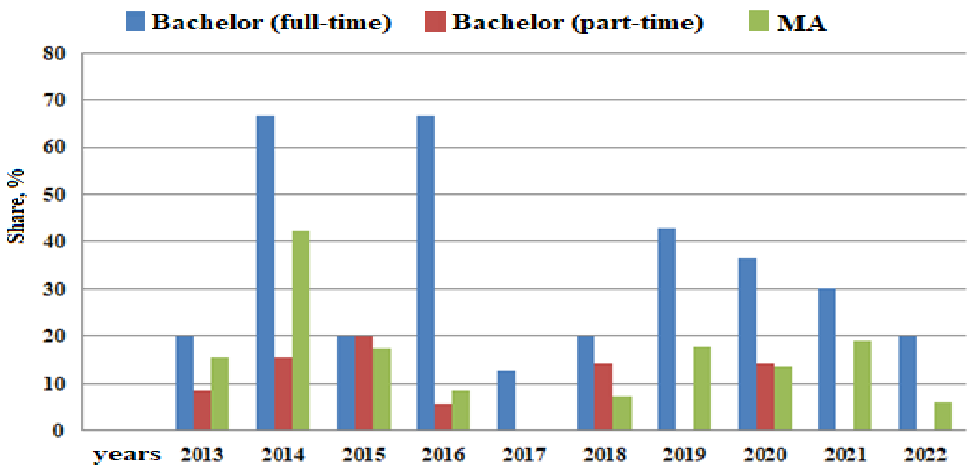


Figure 2.3. Share (%) of theses with themes concerning the field of chemical synthesis

Modeling is an effective method that has been successfully used in recent years at various levels of knowledge. It allows the theoretical study of some phenomena, processes, contributing to active learning with the student's conscious participation, trains logical and creative thinking, develops intelligence, and thus becomes a pleasant and effective method of learning. The modern instructional-educational process must be based on a heuristic spirit in which students can discover unknown relationships and characteristics, rather than being passive and accepting algorithms and concepts dictated by the teacher to obtain new information and knowledge.

Quantum-chemical calculations are a useful mechanism for applying modeling-based strategies to make the chemistry training process more efficient. They allow the trainee to model and visualize molecules, determine their stability, penetrate the essence of some phenomena, understand some processes based on physical laws, calculate the energy of some systems, predict the direction of some reactions, substitution mechanisms, and so on. These methods can be used in training to form and develop practical competences in the use of programs and applications. The use of several modern programs can be used to support the didactic technology for the study of molecules, phenomena, and processes within a university course, as well as the application of more complicated study methods.

Every year, after graduation, bachelor's and master's theses on quantum-chemical calculations and computer-aided chemical modeling are accepted for defense (Table 2.7, Figure 2.4).

Table 2.7. Number of theses defended in cycle I and cycle II with thematic aiming at the field of theoretical chemistry

| **Years** | **Bachelor** (full-time) • Chemistry • Chemistry and biology • Chemistry and physics • Biology and chemistry | | | **Bachelor** (part-time) • Chemistry | | | **Master** • Contemporary chemistry and educational technologies • Ecological chemistry | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total theses, no. | on theoretical chemistry, no. | Share, % | Total theses, no. | on theoretical chemistry, no. | Share, % | Total theses, no. | on theoretical chemistry, no. | Share, % |
| 2013 | 25 | 3 | 12.0 | 36 | 1 | 2.78 | 13 | 0 | 0 |
| 2014 | 9 | 2 | 22.22 | 26 | 0 | 0 | 19 | 0 | 0 |
| 2015 | 20 | 1 | 5.0 | 20 | 0 | 0 | 23 | 1 | 4.35 |
| 2016 | 6 | 1 | 16.67 | 18 | 2 | 11.11 | 24 | 0 | 0 |
| 2017 | 8 | 1 | 12.5 | 17 | 0 | 0 | 17 | 0 | 0 |
| 2018 | 5 | 1 | 20.0 | 7 | 1 | 14.29 | 14 | 0 | 0 |
| 2019 | 21 | 1 | 4.8 | 13 | 0 | 0 | 17 | 1 | 5.9 |
| 2020 | 11 | 1 | 9.1 | 14 | 2 | 14.3 | 22 | 1 | 4.5 |
| 2021 | 10 | 1 | 10.0 | 6 | 1 | 16.7 | 21 | 2 | 9.5 |
| 2022 | 15 | 1 | 6.67 | 5 | 0 | 0 | 17 | 2 | 11.74 |

Bachelor's theses with a theme in the field of theoretical chemistry predominate in the bachelor's degree, both in the full-time section (from 4.8 to 22.22%), and in the part-time section, ranging from 2.78 to 16.7%.

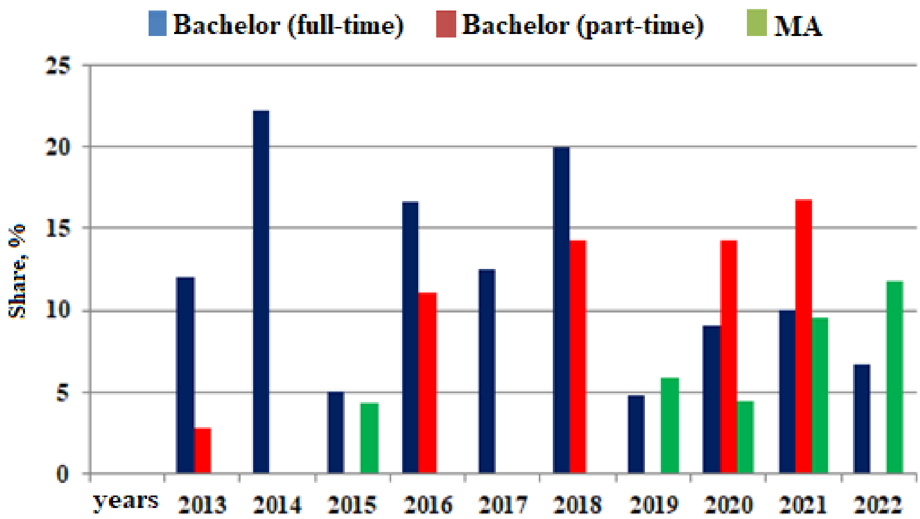


Figure 2.4. Share (%) of theses with themes concerning the field of theoretical chemistry

The realization that natural resources are not infinite, and that exploitation based on purely economic principles often results in irreversible transformations prompted the emergence and incorporation of sustainable development concepts and principles into economic activities. More and more states are beginning to take special measures to ensure the prudent use of natural resources.

As environmental legislation becomes more stringent, the principles of sustainable development and codes of good practices in the field of environmental protection will be transformed from recommendations into mandatory rules. This adaptation should be accomplished through increased legislative flexibility, by encouraging voluntary initiatives while increasing penalties for violations of field legislation, and by facilitating and subsidizing technology transfer between academic, research, and industry institutions.

Ecological instruction is a fundamental component of solving environmental problems during the study of chemistry and is part of the pre-university and university curricula. It is necessary for a student, future chemistry teacher, to train and develop his ecological competence in the following ways:

- to possess a knowledge system specific to the field, outlined by related contents within the limits of the basic university curriculum;
- to have the ability to use and apply the knowledge acquired in teaching-learning-evaluation activities, thus realizing the functionality of the knowledge obtained;
- to have exploratory, investigative, resolution capacities and qualities;
- to integrate and mobilize personal acquisitions, showing, in various school and everyday situations, "behaviors appropriate to the expected attitudes and values" [14].

In order to achieve the ecological education of students, it is necessary for the future chemistry teacher to be helped to understand the importance of:

- acquiring the social-ecological experience by transposing it into the teacher-natural environment system and resulting in changes in personal behavior and student behavior;
- collaboration with actors employed in other sectors of activity and formation of capacities for initiation and development of this collaboration.

Ecology is currently an interdisciplinary science, particularly in that it employs methods, concepts, and notions from other sciences and scientific disciplines to effectively address specific issues, but we can also speak of subdivisions or branches of ecology that arose as a result of the need to deepen certain aspects of ecological study.

Ecology has connections with various sciences or their branches due to the diversity of the problems discussed and the complexity of the aspects studied, such as mathematics, especially statistics, which is used in studies of population dynamics, physics, chemistry, biology, and so on.

In this regard, students who write bachelor's/theses master's possess and apply a set of competences with interdisciplinary character.

Because most students are employed and write their master's thesis in the teaching of chemistry or on ecological topics, their number in the second cycle (Master's) specialties is lower (from 4.35-11.74 %).

Also, in addition to theses on the targeted topics, bachelor's and master's theses with an ecological theme are accepted for support (Table 2.8, Figure 2.5).

Table 2.8. Number of theses defended in cycle I and cycle II with thematic aiming at environmental issues

| Years | **Bachelor** (full-time) • Chemistry • Chemistry and biology • Chemistry and physics • Biology and chemistry | | | **Bachelor** (part-time) • Chemistry | | | **Master** • Contemporary chemistry and educational technologies • Ecological chemistry | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total theses, no. | environmental issues, no. | Share, % | Total theses, no. | environmental issues, no. | Share, % | Total theses, no. | environmental issues, no. | Share, % |
| 2013 | 25 | 7 | 28.0 | 36 | 6 | 16.7 | 13 | 4 | 30.8 |
| 2014 | 9 | 2 | 22.2 | 26 | 5 | 19.2 | 19 | 4 | 21.0 |
| 2015 | 20 | 1 | 5.0 | 20 | 2 | 10.0 | 23 | 5 | 21.7 |
| 2016 | 6 | 0 | 0 | 18 | 1 | 5.5 | 24 | 5 | 20.8 |
| 2017 | 8 | 1 | 12.5 | 17 | 2 | 11.8 | 17 | 1 | 5.9 |
| 2018 | 5 | 2 | 40.0 | 7 | 2 | 28.6 | 14 | 5 | 35.7 |
| 2019 | 21 | 4 | 19.05 | 13 | 2 | 15.4 | 17 | 5 | 29.4 |
| 2020 | 11 | 2 | 18.18 | 14 | 5 | 35.7 | 22 | 7 | 31.8 |
| 2021 | 10 | 4 | 40.0 | 6 | 1 | 16.67 | 21 | 3 | 14.3 |
| 2022 | 15 | 5 | 33.3 | 5 | 2 | 40.0 | 17 | 7 | 41.18 |

When it comes to bachelor's and master's theses on environmental topics, we can see that the number decreased from 2013 to 2017 compared to the years 2018-2022.

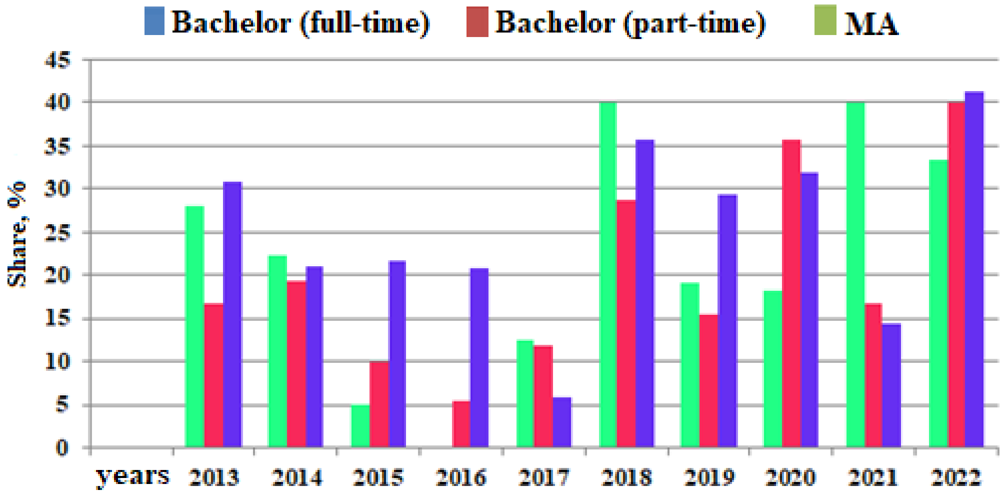


Figure 2.5. Share (%) of theses with themes concerning the field of ecology

According to the data presented above, the percentage of bachelor's theses with an ecological theme range from 5 to 40.0 %, and the percentage of master's theses ranges from 5.9 to 41.18 %. In the case of these three research directions, we can see that the preferences of the students from the first and second cycles of the faculty's chemical specialties are oriented from the topic in the field of chemical synthesis → theoretical chemistry → ecological topic.

Research competences can be developed through both curricular and extracurricular activities. It is obvious that the impact of extracurricular activities is dependent on a number of factors, including the professionalism of the teaching staff, the provision of motivational factors for the educational process, the successful integration of didactic technologies, the diversity of organizational forms, and so on.

It is critical that extracurricular activities begin at the pre-university level (primary cycle, middle school, and high school), because students at this age exhibit maximum curiosity and become involved with satisfaction in processes of discovering nature's miraculous phenomena. The investigation is the most important aspect of extracurricular activities, and regardless of the field of study or the specifics of the organized activity, the most interesting is the research process of some phenomena, legalities, concrete cases, and so on.

Extracurricular activities are distinguished by a high degree of autonomy, which allows for the organization of a diverse range of events with the following characteristics: research; event organization; practical implementation; familiarization with some processes; demonstrative-entertaining experiment; role play; contests, and so on. The value of extracurricular activities is also based on the opportunity for students to be involved in deciding what topics will be covered and how they will be organized. Typically, in extracurricular chemistry activities, the most interest is generated by experiments that produce effects, which are frequently used to study some chemical properties [15]. Changing the color of a solution, obtaining enigmatic crystals, releasing a gas, forming a precipitate, emitting an unusual sound, and self-igniting mixtures are just some of the spectacular effects that can be used to create problematic situations that generate interest in the legalities behind them. It has been established that as the number of experimental activities organized with students increases, so does the preference for professional orientation in favor of specialties in the field of Natural Sciences [16].

Extracurricular activities allow for the study of a variety of processes that are not covered in the curriculum but have the goal of completing the volume of knowledge in the field, such as the study in most cases have an inter- or transdisciplinary character and allow for the development of integrated competences/transversal/crosscurricular in which there are opportunities for the horizontal transfer of knowledge between different disciplines, the energetics of some chemical processes, the determination of the probability of carrying out some substitution or condensation processes, etc. [16-18].

Extracurricular activities are especially important in the development of specific chemistry competences [19]. This encourages the recombination of accumulated knowledge in a different configuration, resulting in the generation of new knowledge, ideas, and products. STEM methodology has recently assumed a special role in ensuring interdisciplinary relationships and the integration of various information.

The "STEM and CRIMINALISTICS" course can serve as an example of integrating information from various fields for the organization of motivating extracurricular activities with the development of investigative competence, in which students carry out detective investigations on concrete cases using knowledge from the fields of biology, chemistry, and physics [20]. Dozens of pilot schools in the Republic of Moldova were outfitted with equipment based on this extracurricular course. School teachers were trained to carry out activities with sector police officers in order to not only develop competences in experimental subjects, but also to instill lasting civic values and attitudes [21]. As a result of the training in this course, a series of competitions in the domain were organized to not only assess the level of competences taught, but also to motivate students and teachers to participate actively in the field. The initiative to move the course from the "Extracurricular Activities" category to the "Optional Courses" category was promoted due to the productive results – a higher level that motivates teachers to organize more activities in the field.

It is critical that students participate in the activities of various non-governmental organizations with social, ecological, and educational objectives outside of school. These activities build character of personality, confidence in one's own strength, and the importance of one's own involvement in solving real-world problems. Many cases have been reported in which non-governmental organizations are run by students, with teachers merely coordinating their activities. This exercise is extremely beneficial for the development of analytical thinking, the formation of managerial qualities, and the discovery of new aspects of the students' personalities that are unknown to the teacher under normal circumstances [22].

Extracurricular activities at the university must be a fundamental component of professional training that is diverse and complex, in which different knowledge from related fields is integrated, cognitive acquisitions are applied in practice, various new and original ideas are developed, and so on. Extracurricular activities and thesis research provide additional opportunities for specialization and depth in areas of personal interest. Students investigate additional sources of information for extracurricular activities, but they also learn about experimental methodology in various fields, methods and equipment used to determine the composition, structure, and properties of chemical compounds, and so on. To realize the value of accumulated knowledge, it must be applied in various contexts and to solve various problems. It is critical to use case studies that present students with various contradictory situations in order to determine the detailed analysis of causes and effects and to develop various solutions.

Students can participate in various specialized circles during their studies at the faculty, being actively involved in some activities to demonstrate demonstrative experiments, in intellectual contests, a fact that influences psycho-emotionally the attitude towards the field of professional training. Students have the opportunity to meet other students from different specialties or years of study within extracurricular circles based on interests, which can serve as a starting point for some professional development relationships not only during studies, but also after college. These professional experiences are extremely beneficial in any field of specialist training, but especially for students studying Educational Sciences who will become teachers of chemistry, biology, geography, physics, and other subjects.

Students can participate in the activities of student organizations, become members of specialized non-governmental organizations, and become members of professional associations. Seminars for the development of professional competences are organized within the faculty, and students are encouraged to attend.

Modern universities organize a variety of informal activities, such as summer schools, in which students have the opportunity to study subjects other than those covered in their study plans. These summer schools are frequently inter-university, allowing participants to meet colleagues from other institutions and form collaborative relationships. Many students are involved in charity activities for various social and age groups, which allows for not only involvement in solving social problems, but also the display of professional qualities.

Thus, extracurricular activities contribute to the development and application of professional competences in all fields of professional training, but particularly in Educational Sciences. Investigation is a distinguishing feature of extracurricular activities that contributes to the development of a research culture. Extracurricular activities have an impact not only on professional competences, but also on their valorization in practical work.

Extracurricular activities complete the study process by contributing to:

- discovery and development of students' capacities in various fields;
- the deepening of knowledge, the discovery, development and capitalization of interests and passions;
- stimulates creativity, imagination;
- possibilities for the affirmation and recognition of performances.

These activities serve as "additional curriculum".

The organization of extracurricular activities within the Faculty of Biology and Chemistry contributes to students' personal development, friendship formation, social integration of young people, and academic performance improvement.

Involvement of students in scientific life is an important activity for career guidance. In this regard, trips to enterprises and factories, both in the country and abroad, are organized, where students have the opportunity to follow various technological processes and learn more about the specifics of some jobs at these industrial centers.

They also have the opportunity to participate in a variety of scientific research projects related to environmental protection, qualitative analysis of food products, determining the quality of natural waters, and the synthesis and study of chemical substances. The results obtained are presented at national and international conferences and are published in specialized journals.

The student scientific circles organized within the faculty provide students with the opportunity to conduct an experiment and analyze the results, to design and manufacture visual aids, laboratory installations, and teaching aids, to write reports and present them at circle meetings, scientific seminars, and so on. Student circles assist students in selecting areas of scientific activity. They discuss the most diverse issues of the studied subjects, allowing for the consolidation and expansion of existing knowledge. Furthermore, the working form of the circles allows the learning process to be organized in such a way that it is not a burden for the students, where they can talk about topics of interest to them, exchange opinions, communicate with the most experienced, ask teachers for advice, and learn how a certain theoretical hypothesis can be implemented in practice in a relaxed and friendly environment. Participation in scientific circles activities is a way to assert oneself, renew one's knowledge, and develop certain abilities.

The "Young Chemist" Circle is active within the TSU Faculty of Biology and Chemistry, with at least four meetings organized during the academic year (2 each semester). The activities are themed, and students from the Chemistry, Chemistry and Biology, Biology and Chemistry, and Ecology specialties from various years of study are actively involved. The circle office is established within the circle, which includes representatives from each specialty (1 member each), where the topic is discussed at a previous meeting and the people who will actively participate in the next meeting are proposed. In addition to students, students from pre-university institutions (high schools, centers of excellence) are frequently invited, sometimes with active participation. This experience connects pre-university and university education and influences young people's professional orientation in schools.

## 2.4. THE PEDAGOGICAL VALUE OF PROJECT-BASED TRAINING IN THE FORMATION OF RESEARCH COMPETENCE

The purpose of project-based learning is to help students develop their creative abilities, create a design culture, create a research algorithm, systematize theoretical ideas, and correlate them with socioeconomic needs. The activity within the projects has an inter- or, more often, transdisciplinary character because it integrates knowledge from various fields, applies theoretical knowledge in practice, evaluates and validates the value of the accumulated acquisitions, highlights the individual's personal qualities, and so on. The most valuable aspect of the project, however, is that it presents a method for the evolution of personal and professional qualities. Throughout the project activity, the educator at the exit acquires a set of knowledge, abilities, and attitudes that are quantitatively and qualitatively superior to those acquired at the start of the process.

The investigation competence not only allows for the assimilation of new information, but also for the development of field conceptions, the formulation of new ideas, and processes influenced by the learner's own experience. As a result, its own trajectory for the formation of research competence is an important feature, allowing the formation of a diverse scientific community. With practical experience, the researcher develops a number of qualities, such as intuition or predictability, which allows the formulation of relatively precise hypotheses about the final results.

Projects can be educational, social, research, environmental protection, entrepreneurial, or a combination: of ecological culture education, innovative-entrepreneurial, of social entrepreneurship, and so on. The more connections between different fields within the project, the more complicated the project, but new opportunities for practical application of study results, comparative analysis of the evolution of the quality of some environmental factors in relation to the development of technologies in industry, agriculture, as well as the analysis of the application of innovative non-polluting production methods, and so on. It is critical for the student to be involved in the transition from projects with narrower approaches to projects with inter- and transdisciplinary approaches.

Students' research activity is transformed from a means of developing creative abilities into a system that improves the quality of chemists' professional training.

The project is used at various levels in college studies: at the level of concrete courses (within individual work); annual projects (as an intermediate stage for the elaboration of graduation theses); in various competitions of student projects (funded and unfunded); in extracurricular activities; in professional or profile associations; in individual or collective research projects; elaboration of the bachelor's / master's thesis. The development of a graduation thesis of cycle I or II requires the involvement of the most valuable competences for the investigation of a current subject with socioeconomic impact.

The activity in research projects is unique to university education and contributes to the students' introduction to design techniques, as expressed in the elaboration of year and bachelor projects. The actual activity occurs during project meetings:

- presentation of the topic and commencement of its investigation, for which bibliographic recommendations are made, the methodology of the investigation, the collection of data and their interpretation, the calculation method, the execution of the drawings;
- work on the project, where projects are examined, bibliographical recommendations are made, and if necessary, rejected;
- presentation of the project, in which the approved projects are supported on the basis of the justifying memorandum (which includes the title, the objectives pursued, the stages of solving);

- scientific documentation, experimentation, data collection and processing on the site of experimental practice, completion, and application; calculations, execution of drawings, diagrams, graphics, text writing, and so on.

During the project activity, the student practices problem-solving competences. The capacity to think original and elaborate optimal solutions for specific situations highlights some qualities such as cleverness, courage, and the ability to think outside the box. Working in projects ensures personal development autonomy, strengthens the capacity to make quick decisions, and enables the selection of the most efficient option from all variants considered.

The application of the projects allows the student:

- to consolidate and demonstrate their own style of thinking and activity;
- to be actively involved in the investigation activity;
- to develop capacities to carry out independent educational activities;
- to elaborate algorithms for carrying out different researches;
- use techniques such as observation, problem formulation, correct hypothesis and practical justification;
- express their point of view clearly and correctly, using field-specific terms;
- identify relevant information from various sources to complete the study;
- to successfully combine different own special technologies and known research methods for conducting the investigation;
- prepare and conduct surveys, questionnaires, interviews and process the data obtained, etc.

The activity within the projects provides the specialist with flexibility in the process of adapting to new activity conditions, as well as the option of professional reorientation in the event of the need to change the field of activity in the context of dynamic labor market changes.

Students in the faculty can participate in various research projects outside of the study program, which can be carried out both in the basic faculty's subdivisions and in other research institutions. Students' participation in research projects has several effects, including: familiarizing students in depth with a research direction, the history of research development in the field, personalities who have contributed to the development of the field, priority objectives for research development in the field, and so on; the specific methodology for investigations in the field; the possibilities of collaboration with other research centers; participation in scientific events; publication of the results, familiarization with the most valuable results in the field from specialized literature and international invention salons – a fact that can orient the researches in the direction of global tendencies, with the obtaining of economic effects and the development of theoretical knowledge in the field, and so on. Experience in research projects is extremely beneficial in the development of professional competences and frequently determines the field of activity after graduation.

Based on the finalities set out in the study programs, the formation of a competent specialist would include creative search and research abilities. In this regard, the modern specialist should possess not only basic knowledge and specialization, but also certain specific competences for creative problem solving in a variety of practical situations, as well as to constantly develop the ability and quickly adapt to changing conditions.

The development of the bachelor / master thesis focuses on the further development of the student's creative and cognitive abilities, and it aims to consolidate and expand theoretical knowledge and in-depth study of the chosen topic as the final stage of the student's education at university. Many students are already working in their chosen field during their final years of study, and this is frequently considered when selecting a topic for a thesis. In this context, in addition to studying the specialized literature, one can include one's own practical experience on the topic, which increases the paper's scientific value.

Future chemists learn to independently develop a work plan, select the necessary literature, use various tools and equipment, carry out experiments independently, process their results through mathematical processing and analysis of results, write a report on the activity carried out, and apply the knowledge in solving some field-specific problems. The scientific results obtained through student research activities are presented at various scientific forums, such as thematic seminars, round tables, annual student scientific conferences, national and international scientific conferences, and are published in conference papers or journals (Table 2.9, Figure 2.6).

Table 2.9. The number analysis of publications of chemistry students (I$^{st}$ and II$^{nd}$ cycle) in the Biology and Chemistry Faculty, period of 2016-2021

| **Years** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** |
|---|---|---|---|---|---|---|
| **No. of publications** | 6 | 9 | 10 | 15 | 18 | 27 |

The number of publications by first and second cycle students increased significantly over the five-year study period. The number of publications increased 4.5 times between 2016 and 2021.

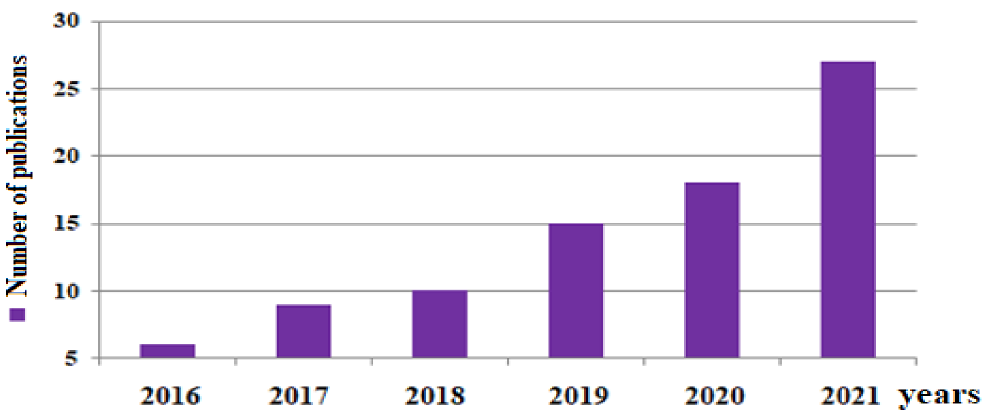


Figure 2.6. Evolution of the number of publications of chemistry students (I$^{st}$ and II$^{nd}$ cycle) of the Faculty of Biology and Chemistry, 2016-2021

This increase may also be conditioned by the active participation of TSU students in various projects, including student research projects, which are chosen annually and focus on various research topics. Among the fundamental criteria for project selection are:

- ensuring research with an inter- and transdisciplinary character based on the inclusion of students from different specialties, but also the research objectives formulated in the project;
- ensuring the continuity of the transmission of experience by including students from the first and second cycle;
- conducting impact studies in the field of research by developing new materials or solutions to concrete problems;
- participation in various scientific events for the dissemination, publication of the results obtained, etc.

During the period 2018-2022, the faculty funded 11 student research projects with the following titles:

1. Synthesis and investigation of the properties of new coordinating compounds based on ligands with various functional groups (2018);
2. Application of higher plants, algae, and fungi as bioindicators of environmental quality in Moldova (2018);
3. Quantum-chemical investigation of the energy stability of some molecules and the energy profile of the mechanisms of some chemical reactions (2019);
4. Application of bioindicators in the monitoring of aquatic and terrestrial ecosystems in Chisinau municipality (2019);
5. Design and synthesis of coordinating compounds based on 3d metals and ligands with various functional groups (2020);
6. Establishing the interaction relationships of bioindicators with environmental factors in the conditions of the municipality of Chisinau (2020);
7. Synthesis and theoretical investigation of new compounds, quantum-chemical investigation of energy stability, and energy profiles of chemical reaction mechanisms (2021);

8. Monitoring and evaluation of the quality of Chisinau's aquatic and terrestrial ecosystems using bioindicators (2021);
9. Theoretical and experimental investigation of complex compounds containing transition metals and polyfunctional ligands, as well as amino acid derivatives (2022);
10. New inorganic-organic hybrid materials based on polyfunctional ligands and metals of the "s" and "d" types (2022);
11. Optimization of the *in vitro* micropropagation protocol of *Actinidia Arguta* plants (2022).

So, 47 students from the first and second cycles were included in the projects over the course of five years.

The findings of student scientific projects are presented and published in papers presented at various scientific conferences or journals (Table 2.10, Figure 2.7).

Table 2.10. Number of publications within the projects

| **Years** | **Biology projects** | **No. of publications** | **Chemistry projects** | **No. of publications** |
|---|---|---|---|---|
| **2018** | 1 | 2 | 1 | 2 |
| **2019** | 1 | 6 | 1 | 5 |
| **2020** | 1 | 3 | 1 | 2 |
| **2021** | 1 | 1 | 1 | 2 |
| **2022** | 1 | 1 | 2 | 4 |

Previously, in Figure 2.6, data were presented that confirmed an increase in the number of college student publications, which appears to contradict the data in Figure 2.7.

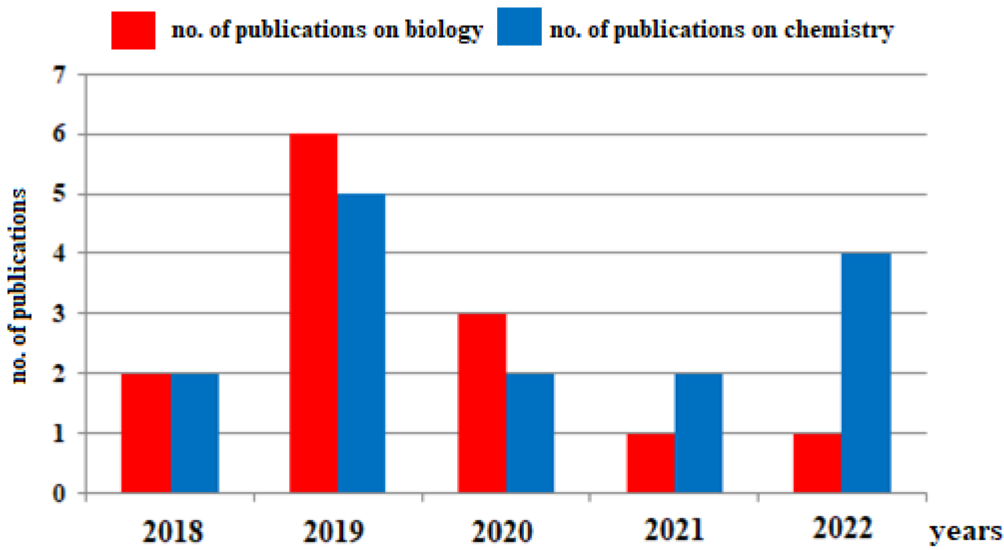


Figure 2.7. Number of publications within student research projects, years 2018-2022

The COVID 19 pandemic, which reduced experimental activities, caused a significant decrease in the number of publications in experimental projects in the period 2020-2021. The total number of publications shown in Figure 2.6 has increased as a result of work in the field of Chemistry Didactics.

Thus, we conclude that the involvement of students in research projects contributes to increasing professional competences, determining areas of activity based on their own interests, but also to accumulate the results of scientific activity expressed by participating in scientific events and publishing materials.

## 2.5. INSTRUMENTAL METHODS FOR ANALYZING THE COMPOSITION AND STRUCTURE OF COMPOUNDS. BIOLOGICAL METHODS. BIOLOGICAL TESTING

The possibility to achieve various ligand coordinations, the various coordination capabilities of transition metals, the synthesis conditions, and the addition of other complexones into the reaction medium can result in a structural variety of the produced complexes. Examples of compounds in which inorganic anions exhibit bridge ligand qualities for producing di- and polynuclear compounds are known, along with the potential for the coordinating paoH bridge-ligand.

After collecting the coordinating compound, separating it from the solution, and purifying it, an interdisciplinary inquiry procedure involving physical and physico-chemical research techniques (elemental analysis, IR spectroscopy, UV-Vis, NMR, thermal analysis, crystal structure determination by diffraction X-rays, etc.) and evaluating the coordinating compound as a catalyst or stimulator of biological or industrial processes continues. The characteristics that the coordinating compound will exhibit can be predicted based on its structure and chemical composition.

*Methods of obtaining crystals.* A high purity product is required to accurately determine the composition and structure of compounds. Crystalline substances are most frequently researched in the chemistry of coordinating compounds, which enables the transmission of high-quality information about the compound. The clarity of the crystal's structure is mostly determined by the quality of the crystal from which data are collected after X-ray diffraction analysis. Depending on the system, crystal growth might take anywhere between minutes and months. The use of different solvents allows the crystals to grow separately from each other. The use of solvent mixtures allows for the manipulation of the solubility of dissolved substances, both inorganic and organic. If a particular range of proportions appears to be more successful in the production of crystals, it can be investigated more closely by reducing the difference between successive mixtures.

*The determination of carbon, hydrogen, and nitrogen content.* The elemental analyzer Elementary Analysensysteme GmbH Vario El III was used to analyze the content of C, H, and N elements in the investigated compounds at the Institute of Chemistry's Center for Physical Chemistry and Nanocomposites.

*The IR spectra* were obtained using KBr pill samples or Vaseline oil suspensions and the FT IR Spectrum-100 Perkin-Elmer spectrophotometer in the 400 - 4000 $cm^{-1}$ range at the Institute of Chemistry's Center for Physical Chemistry and Nanocomposites. The value of the investigated substances' IR spectra consists in their unique characteristics, which can serve as evidence of the presence of one or more groups, isomers, and geometric structures.

*$^{1}H$ and $^{13}C$ NMR spectra* were recorded on the Bruker Avance 400 spectrometer with $^{1}H$ operating frequency of 200.13 and 400 MHz respectively in DMSO-$d_6$ solutions using the internal TMS standard. The signals were expressed in ppm. The studies were performed at the Center for Physical Chemistry and Nanocomposites of the Institute of Chemistry. The purpose of using the method was to elucidate the composition and structure of the analyzed compounds, at the same time - the study of the stability of complexes in solutions.

*X-ray diffraction.* For compounds **1-2** and **5-7** the structural data were obtained at room temperature with Xcalibur CCD diffractometer "Oxford Diffraction", using MoKa radiation ($\lambda$=0.71073 Å), graphite monochromator and $\omega$ scanning. Unit cell parameters checked for the entire experimental data set. Determination of elementary cell parameters and processing of experimental data were performed using the CrysAlis Oxford Diffraction Ltd. program. Crystalline structures determined by direct methods and specified by the least squares method (LSM) in the complete anisotropic variant for atoms (SHELX-97) [23]. The positions of H atoms were determined from Fourier syntheses, the other H atoms were calculated for geometric reasons. The drawings were made using the Mercury program [24].

*Microbiological methods.* The use of coordinating compounds as stimulators of the biological activity of different organisms is one of the directions required for solving some problems in medicine, food industry, agriculture, etc. [25].

Due to the increased reaction to environmental changes, adaptive metabolism, short development cycle, synthesis of a wide range of important bioactive substances, microorganisms are comfortable and cost-effective objects for various research. Among the important substances synthesized by microorganisms are enzymes (pectinases, amylases, cellulases, proteases, lipases) that have various uses in different economic and social spheres [26, 27].

The need to obtain increased amounts of enzymes imposes the goal of developing new biosynthesis technologies. Coordinative compounds are of interest as chemical stimulants. The nutrient environment stands out among all the external environmental factors that influence the biological processes in the microbial cell. Namely the composition of the nutrient environment regulates the development of microorganisms and the activity of biosynthesis, more than any other factor.

The complex generating metal, which can attribute to the complex both biostimulatory and inhibitory properties of physiological processes, plays an important role in the manifestation of biostimulatory properties.

The ligands in their composition play an important role in the manifestation of the properties of metal complexes, which create stable complexes with the ions of transition metals that differ in composition, structure, and properties due to the large set of donor atoms. Biologically active substances, used as ligands in metal complexes, significantly improve their efficiency.

The biological properties of the tested complexes were evaluated based on their impact on the fermentation process of the micromycete *Aspergillus niger* CNMN FD 06, which is an active producer of amylolytic enzymes that hydrolyze starch-containing substrates under both normal (at pH 4.7) and extreme acidic pH conditions (pH 2.5).

The cultivation was performed by the deep method on a medium with the previously chosen composition [28, 29], the pH of the medium – 5.0, the culture temperature 28-30 °C, under constant stirring, with a rotary stirrer at a rotation speed of 180-200 r/min.

The complex compounds were introduced into a sterile nutrient medium at concentrations of 5, 10, 15 mg/L, together with the seed material. As a control medium served the one without the addition of complex compound. The complex compound's effect on the amylase activity of *Aspergillus niger* micromycete CNMN FD 06 was measured over time on the 5th and 6th day of cultivation, which corresponds to the strain's maximum biosynthesis period under classical cultivation conditions.

The determination of amylolytic activity was performed photocolorimetrically by determining the degree of cleavage of starch to dextrins with different molecular weight in standard conditions (pH 4.7) and in extreme acidic conditions (pH 2.5) [29].

Biological tests were performed in the Enzymology Laboratory of the Institute of Microbiology and Biotechnology, Chisinau, Republic of Moldova.

*Modeling of molecular systems.* Quantum-chemical calculations are a useful mechanism for applying strategies to streamline the modeling-based chemistry training process, as they allow the trainee to model and visualize molecules, determine their stability, penetrate the essence of phenomena, understand some processes based on physical laws, calculate the energy of some systems, predict the direction of some reactions, the substitution mechanisms, and so on. The energy status of some chemical systems as well as the energy profile of some intermediate reactions have been investigated [30, 31]. A number of parameters related to molecular structure, physical/chemical/biological properties, and so on can be correlated and predicted using quantum-chemical calculation methods.

The use of several modern programs can be used to support the didactic technology for the study of molecules, phenomena, and processes within a university course, as well as the application of more complicated study methods. GAMESS is one of them, and it contains various calculation methods, beginning with molecular dynamics and mechanics, semi-empirical methods, ab initio methods based on Hartree-

Fock theory, or methods based on density function theory, and it can be used to calculate a wide range of molecular properties [32, 33].

## 2.6. METHODOLOGICAL OPTIONS REGARDING THE FORMATIVE VALUE OF RESEARCH IN OBTAINING NEW MULTIFUNCTIONAL MATERIALS BASED ON COORDINATING COMPOUNDS FOR THE DEVELOPMENT OF CHEMISTRY RESEARCH CULTURE

The global economy is dependent on the level of development of science, and their progress is largely facilitated by the evolution of science, particularly chemical and material sciences. When a number of natural resources become scarce, the development of new materials with useful properties presents an optimal solution for socioeconomic development.

Recently, there has been a growing emphasis on the relationship between the composition, structure, and biological properties of coordination complexes. An attempt is made to find a series of complexes with varying degrees of stability based on the nature of the donor atom of the ligands that coordinate to the central atom in the apical position. The investigation of transition metal compounds with oxime ligands is a broad area of coordination chemistry. The fascination with them is explained not only by the wide variety of these compounds and their structural peculiarities, but also by their chemical and physical properties, which form the foundation of their practical applications (in analytical chemistry, catalysis, extraction processes, as semiconductors and models of biological systems).

One of the deciding priorities in the use of α-dioximes in the synthesis of complexes with transition metals is the formation of chelates with high stability. The incorporation of different types of ligands into the axial positions of the octahedron allows for the diversification of the complexes' composition, structural characteristics, and spectrum of properties:

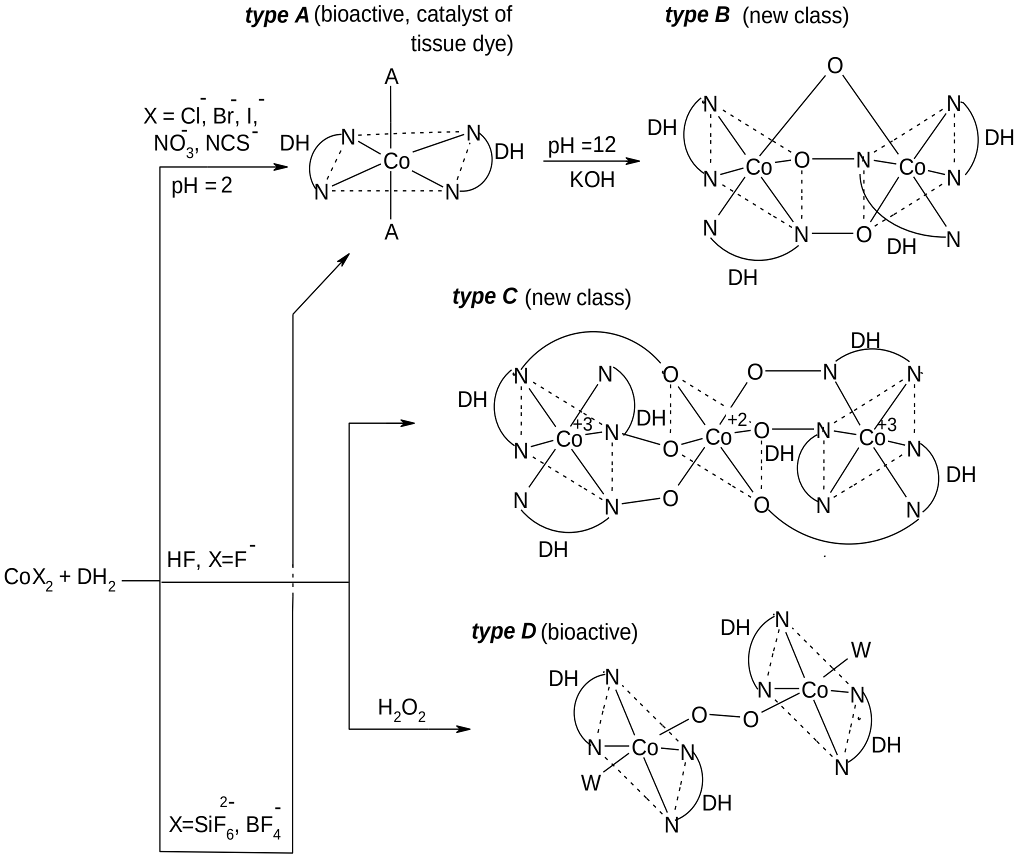


Figure 2.8. Types of coordination compounds with dimethylglyoxime obtained depending on the synthesis conditions

The dioximates' varied structure is due to the different synthesis conditions (pH of the solution, etc.), the nature of the axial ligands and anions in the external sphere, and so on. The addition of hydrogen peroxide to the reaction medium, for example, resulted in the formation of cobalt complexes of various valence and molecular architecture.

With the discovery of coenzyme $B_{12}$, a cobalt coordinating compound, and the understanding of its importance in physiological systems, a lengthy process of developing model molecules that could fit into biochemical processes and perform similar or even greater functions was initiated. A massive amount of research has been conducted to investigate the structural features and properties of new compounds in understanding the mechanisms of interaction and the conditions under which they are produced. To diversify the vitamin $B_{12}$ molecule, a series of co-complexes with ligands of varying coordination capacity that repeat the basic molecule's molecular architecture were synthesized [34].

Interdisciplinary training leads to the growth of the ability to multilaterally characterize a phenomenon or process in nature. Only in this context can a phenomenon and theoretical knowledge's practical applications be fully explained. Currently, research clearly highlights the trend of promoting projects with an integrated character, such as determining the environmental effects, calculating the profitability of new technologies in comparison to existing analogues, and so on. Within the framework of the integrated study, the information volume of notions and theories increases and a unitary scientific picture of the world is formed, which possesses dialectical integrity. Namely, in the areas of intersection of different branches of science, premises appear for the study of complex phenomena [35].

Creating new compounds with useful properties is a major current focus in Chemistry and Materials Science. The chemical synthesis of molecules that display patterns of vitally important compounds enables the direction of processes required for agriculture, medicine, industry, and so on.

Heterometallic trinuclear compounds with zinc dioximes are of interest for obtaining monomolecular magnets [36], based on $Cr^{III}Zn^{II}Cr^{III}$ and $Mn^{IV}Zn^{II}Mn^{IV}$ complexes, which contain oximate anions as bridging ligands.

The structural diversity of 1,2-cyclohexanedioximines/1,2-cyclohexanedioximates of zinc and cadmium is represented by mono- and binuclear compounds, as well as coordination polymers, in which dipyridine and dicarboxylic compounds act as coordinating agents as bridging ligands [37, 38].

The relationship between the nature of the initial salt anion and the architecture of the coordination compounds obtained was determined for some of these compounds. Dioximates have the potential to be used in the electrocatalytic production of hydrogen [39]. A large number of clathrochelate *tris*-dioximates have been obtained as potential cancer treatments. Clathrochelate self-assembly reactions and interactions with nucleic acids can be used in immunology and molecular biology [40].

In terms of the practical applicability of coordinative compounds based on oxime ligands, there are currently several directions in which the representatives of this class can be successfully used: the development of artificial models of vitally important biological molecules; the development of effective biotechnologies for obtaining enzyme preparations used in various branches of the food and pharmaceutical industries; the development of compounds with useful properties, etc.

Because microorganisms are recognized as economically advantageous sources for obtaining a wide range of important bioactive substances, modern biotechnology places a special emphasis on the directed synthesis of bioactive substances by microorganisms. Coordinating compounds have the ability to positively influence enzymogenetic processes due to the presence of microelements (Co, Zn, Mo, etc.) linked with organic coordinating agents in their molecules, which form systems with properties distinct from those of the initial substances [12].

Cobalt-containing coordination compounds can stimulate vitamin $B_{12}$ biosynthesis in the alga *Spirulina platensis* [12]. These studies created premises for the initiation of syntheses in order to develop synthetic analogs of natural systems, the modeling of biological molecules and the analysis of their influence on the processes taking place in the cell. Other elements are equally necessary for organisms.

The results obtained based on testing the influence of Co(III) dioximates on the physiological processes of some strains of micromycetes allow the conclusion that from the series of analyzed complexes can be selected: biostimulators of the enzymogenetic processes of fungi, catalysts of biomass accumulation processes, stabilizers of biochemical processes of vital importance in unfavorable conditions, accelerators of the biological development of microorganisms, reducing the technological cycle by 24-48 hours, i.e. up to ~30% of the duration of the entire cycle, a fact that is of interest from an economic point of view, etc.

The researchers decided to investigate the effects of cobalt(III) dioximates on the physiological processes of some algae. It has been established that some coordinating compounds in this series stimulate biosynthetic processes in red algae *Porphyridium cruentum*: the accumulation of lipid oxidation products in the biomass, followed by the intensification of lipid biosynthesis, determines the ability of cells to maintain their viability [41].

The use of transition metal coordinating compounds for the treatment of the seeds of some higher plants (sugar beet) resulted in an increase in the content of assimilatory pigments, harvest and total sugar production per surface unit, an 11.5% increase in rhizocarp harvest compared to the control, and a 6.1% increase compared to the yield increase provided by the treatment with the closest technical solution [42].

Since Zn(II) and Cd(II) dioximates are little studied, but classical dioximes as bidentate ligands are convenient objects to form stable chelates, it was decided to carry out a series of syntheses for the preparation of complex compounds based on these ligands.

These scientific arguments support the effectiveness of approaches to interdisciplinary contents in the training of chemical specialists.

The use of coordinating compounds to stimulate physiological processes in fungi is justified by several reasons [12]:

- Because of their structure, metallocomplexes are similar to natural biological complexes, which are regulators of organisms' vital functions (chlorophyll, hemoglobin, vitamin $B_{12}$, etc.). Nature has determined the worth of macromolecular biomolecules in performing vital biological functions for organisms.
- The complex generators in most metal complexes are biometals – irreplaceable biological catalysts whose action is linked to proteins and specific enzymes. Metal ions are essential in enzyme catalysis processes.

These studies created premises for the initiation of syntheses in order to develop synthetic analogs of natural systems, the modeling of biological molecules and the analysis of their influence on the processes taking place in the cell. Other elements are equally necessary for organisms.

The finalities of initial professional formation, according to national and international practices, are to train competent and competitive specialists for effective social insertion. As a result, initial professional training must focus on the formation of professional competence through integrated interdisciplinary content.

As a result, there is a global trend toward the training of highly qualified specialists with employment opportunities in a variety of adjacent fields. To demonstrate its effectiveness in this context, the methodology of training the initial professional competence of the chemical student must focus on the interdisciplinary correlation of the contents of the chemistry, biology, physics, and other courses.

We consider the interdisciplinary teaching-learning-evaluating process to be an important condition for achieving a modern, formative education. The correlation of knowledge from different educational disciplines will significantly contribute to students' education, the formation and development of flexible thinking, and their ability to apply theoretical knowledge in practice; knowledge correlation better fixes and systematizes knowledge because one discipline aids in the understanding of the other.

Students' thinking abilities will improve as a result of the interdisciplinary relationships used in the educational process. When the teacher uses real-life examples, chemistry students participating in interdisciplinary learning activities will find the content much more interesting and engaging.

Unlike traditional higher education, which focuses on domain-specific knowledge and the development of general competences, this type of higher education aims to develop cross-disciplinary capacities, which include the ability to shift perspectives, synthesize knowledge from various disciplines, and deal with complexity.

These scientific arguments support the efficacy of interdisciplinary approaches to content in the training of chemical specialists.

Interdisciplinarity can solve a number of problems related to student training, development, and education, as well as lay the groundwork for an integrated approach to solving complex real-world problems.

Interdisciplinary links are an important condition and the result of a complex approach to training and educating students in this context.

As a result, the interdisciplinary *Chemistry for Life Curriculum – Integrated Research* is designed based on four learning units:

1. *Obtaining compounds with useful properties* – aims at the chemical synthesis of new coordinating compounds – composition study based on physical methods of analysis – calculations on the energetics of assembled chemical systems – use as stimulators of biosynthetic processes. This module will lead to the formation of the *Research Competence* by the fact that the initial student will propose an algorithm for the synthesis of the coordinating compound by elaborating the mechanisms of using different ligands, different metals with biological activity, synthesis conditions, etc.
2. *Instrumental methods for analyzing compound composition and structure. Biological techniques. Biological testing* aims to investigate some modern instrumental methods of deciphering the composition and structure of chemical compounds, as well as some biological methods and biological testing. As a result, the research competence will be formed by the fact that the student will be able to determine whether the obtained compound corresponds to the previously established composition and structure by using different contemporary physical analysis methods to determine the composition and structure of chemical compounds, as well as the use of different biological testing methods of compounds synthesized on biological media regarding the stimulation of biological processes.
3. *Compound composition and structure modeling methods* – aims to study inorganic and organic molecules / chemical phenomena - computational modeling - analysis of the most stable models - molecular structure conclusions / process development - computer

processing of the results - data analysis and conclusion drawing. Within this module, you will develop the digital competence (specific to the field of chemistry) by the fact that the chemical student, using different applications, digital software, will be able to model molecular systems, certain chemical phenomena, processes that take place between molecular systems, the direction of one or another process, determining the stability of the investigated systems, etc.

4. *Ecological auditing and methods for determining the quality of environmental factors* aims to analyze the quality of environmental factors using sensors. You will form *ecological competence* as a result of studying this module, where chemical students will acquire abilities to determine the quality of environmental factors by integrating digital competence with the use of sensors (digital application connected to the computer).

The Republic of Moldova developed the Concept of the National Strategy for Sustainable Development, stating as basic principles the greening of knowledge, mental remodeling, and reorganization of the educational, ethical-moral system toward new intellectual and spiritual values. Currently, it is certain that the educational process is environmentally friendly and that it is a priority factor in scientific-pedagogical research. Ecological training is a process in which the personality becomes aware of environmental values and concretizes certain directions required for a deeper understanding and recognition of man's interrelationship with the environment.

After completing the course, the chemical students will also form their professional communication competence through the capacity to communicate the results of the research, the results of the analysis of the composition and structure of the obtained compounds, the results of modeling, the results of the analysis of environmental factors, etc., by drawing up and presenting different reports, as well as the *competence of continuous professional training* developed through a totality of activities oriented to the requirements of the present and of the initial professional training, as well as the adaptation to the new requirements of the professional activity, towards the assimilation of new knowledge and skills.

***Obtaining compounds with useful properties***

Socioeconomic evolution necessitates the development of new solutions based on multifunctional materials, which would compensate for the deficit caused by the ratio of needs to sources and the existing natural potential by increasing the efficiency of some processes.

The capacity to synthesize chemical compounds is an important objective in the training of a chemical specialist. This process can be reproductive (synthesis of known compounds) or productive-creative (new compounds). Chemical synthesis is divided into several stages: planning, training, achievement, analysis of synthesis products, determination of composition and structure, and so on. The identification of areas of practical implementation of chemical compounds argues for the usefulness of a chemical synthesis. The incorporation of several components within a single compound, such as metal cations, organic or mineral ligands, bioelement anions, and so on, allows for the formation of coordinating compounds with various useful properties, in which the conjugation of separate components results in the manifestation/ amplification of special properties.

The assembly of coordination compounds is planned based on the prediction of the interaction of the complex-generating metal salt with ligands containing electron donor atoms capable of coordinating to the metal ion, the coordination number of which determines the molecular architecture, and the specificity of the ligand can influence the coordination compound's nuclearity. The synthesis is prepared by selecting the optimal conditions for its subsequent realization.

Synthesis planning and condition selection necessitate imaginative, often abstract thought. It is critical to understand the field's previous achievements, the trends and directions promoted by various research groups, knowledge of the specifics of the synthesis conditions, the availability of reagents and the necessary equipment, the yield of chemical syntheses, the economic effect, and the possibility of technological transfer for the efficiency of different processes in the basis of new compounds, and so on. Thus, the planning of new chemical compound synthesis focuses on several components, including logistics (ensuring the necessary conditions), creativity (outlining new ideas), economics (return on investment and benefits), and prognostication (study of the probability of achieving the proposed objectives). To understand the most likely evolution in obtaining the reaction products, the experimenter must intuit the possible variants of the process. The psychomotor functions are sharpened during the synthesis, allowing processes like observation, intuition, and comparison to register the specific signs of the reaction to understand the direction of the synthesis.

1,2-cyclohexanedioxime coordination compounds can be mono- and binuclear, as well as coordination polymers of various dimensions in which dipyridine and dicarboxylic ligands act as bridges [34, 43, 44].

A series of syntheses were performed in order to obtain some zinc and cadmium compounds with 1,2-cyclohexanedionedioxime and some ligands with electron-donating atoms (N, S), such as thionicotinamide (*S-Nia*), nicotinamide (*Nia*), and isonicotinamide (*INia*). New coordination compound synthesis:

$[Zn(CH_3COO)_2(NioxH_2)(S\text{-}Nia)(H_2O)]DMF$ (**1**),

$[Zn(CH_3COO)_2(NioxH_2)(DMF)(H_2O)]$ (**2),**

$[Zn(CH_3COO)_2(NioxH_2)(Nia)(H_2O)]$ (**3**),

$[Zn(CH_3COO)_2(NioxH_2)(Inia)(H_2O)]$ (**4**), $[Zn(CH_3COO)_2(paoH)_2]$ (**5**), $[Zn(paoH)_2(DMSO)_2][BF_4]_2$ (**6**), $[Zn(NCS)_2(paoH)_2]$ (**7**) a was created by stirring heated solutions containing zinc or cadmium salts (acetates, tetrafluoroborates, thiocyanates) and organic molecules as coordinating agents. Depending on the nature of the dissolved substances, the solvent mixtures were composed of methanol, dimethylformamide, and dimethylsulfoxide in various proportions [45, 46].

The bands at 1662-1646 $cm^{-1}$ in the IR spectra of complexes **1-4** are due to $\nu(C{=}N)_{oxime}$ vibrations, and the bands at 1076-1063 $cm^{-1}$ are due to ν(N-O)$_{oxime}$ vibrations. The oscillations of the pyridine ring are represented by the band at 1616-1603 cm$^{-1}$ in compounds **5-7**.

The maximum intensity bands at 1554-1543 and 1415-1401 cm$^{-1}$ are caused by carboxyl group $\nu_{as}(CO_2)$ and $\nu_s(CO_2)$ vibrations. The presence of the acetate ion also indicates the presence of the bands $_{\nu as}(CH_3)$ 2951-2938 and $\nu_s(CH_3)$ 2875-2860 cm$^{-1}$. The presence of the $NH_2$ group's valence bond is indicated by the bands at 3328 (**1**), 3306 (**3**), 3298 (**4**) cm$^{-1}$ and 3161 (**1**), 3174 (**3**), 3177 (**4**). Compound **1**'s strongly highlighted band at 1032 cm$^{-1}$ could be caused by C=S bond vibrations.

It was decided to use some heterofunctional ligands to monitor the competitiveness of different functional groups in the complexation process in order to study the structural diversity and exchange reactions at the metal cation. The molecular structure of compounds **1** and **2** was determined using single crystal X-ray diffraction. When zinc acetate interacts in a 1:1 ratio with $NioxH_2$ and S-Nia in a $CH_3OH$:DMF:$H_2O$ (3:1:1) medium, the complex $[Zn(CH_3COO)_2(NioxH_2)$ (S-Nia)$(H_2O)]$DMF (1) is formed, in which two acetate anions, $NioxH_2$ molecules, S-Nia, and water coordinate to one zinc ion (Figure 2.9).

The $NioxH_2$ ligand forms a pentacyclic chelate ring with an N-Zn-N endocyclic angle of 72.61(19)° and Zn-N distances of 2.173(5) 2.194(5), while the axial S-Nia ligand coordinates monodentately through a heterocycle nitrogen atom with a Zn-N distance of 2.181(5) Å.

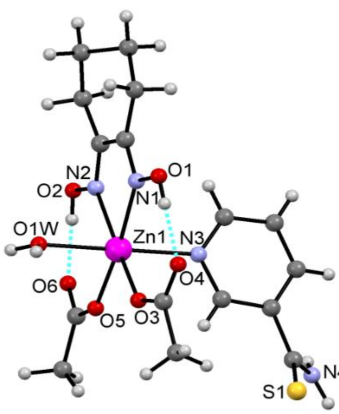


Figure 2.9. Molecular structure of the coordinating compound $[Zn(CH_3COO)_2(NioxH_2)$ (S-Nia)$(H_2O)]\cdot$DMF

All ligands containing the O atom coordinate to monodentate metal atoms and two acetate-anions complete the equatorial plane, the water molecule occupying the second axial position. The metal-O distances are in the range 2.036(4)-2.135(4) Å.

The compound [Zn($CH_3COO)_2$(Niox$H_2$)(DMF)($H_2O$)] (**2**) was obtained by reacting zinc acetate with Niox$H_2$ in a ratio of 1:1.5, in $CH_3OH$:DMF medium. Niox$H_2$ molecules, two monodentate acetate anions, the water molecule and DMF coordinate chelately to the metal cation through the nitrogen atoms of the oxime groups (Figure 2.10).

The coordinated polyhedra of the metal atoms show distorted octahedra formed by the set of $N_2O_4$ donor atoms. The Niox$H_2$ ligand forms a pentacyclic chelate ring with the N-M-N endocyclic angle equal to 71.45(17)° and the M-N distances equal to 2.208(3)Å.

All oxygen-containing ligands coordinate to monodentate metal atoms, two acetate anions complete the equatorial plane, solvent molecules, water and DMF occupy the axial positions. The metal-O distances in the coordination polyhedra are in the range 2.042(3)-139(4)Å.

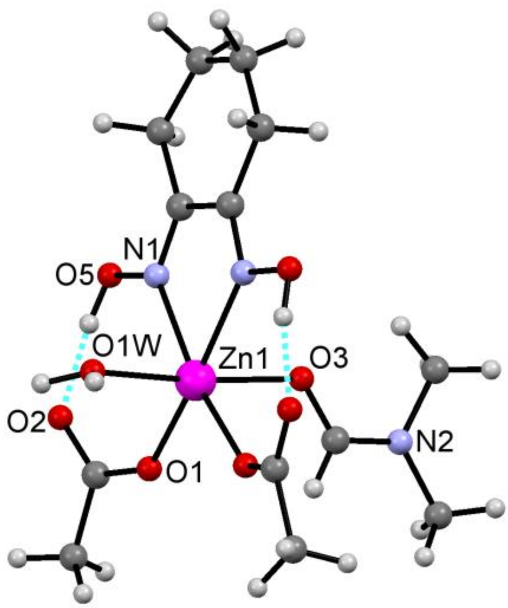


Figure 2.10. Molecular structure of the coordinating compound [Zn($CH_3COO)_2$(Niox$H_2$)(DMF)($H_2O$)]

The oxygen atoms of the acetate anions not involved in coordination with the metal are linked by internal O-H···O hydrogen bonds to the oxime groups. The association of mononuclear complexes in crystals occurs based on OH···O hydrogen bonds with the participation of water molecules and acetate anions. Only van der Waals interactions are present between the chains in the crystals.

In the IR spectra of compounds **5-7** there are bands indicating the presence of the paoH ligand: the band at ~1650 $cm^{-1}$ is caused by the $\nu(C{=}N)_{oxime}$ vibrations, at ~1600 $cm^{-1}$ – vibrations of the pyridine ring, at ~1060 $cm^{-1}$ – $\nu(N–O)_{oxime}$ vibrations, the band at ~638 $cm^{-1}$ is due to the in-plane distortion of the pyridine ring. The strong intensity bands at 1545 and 1411 $cm^{-1}$ in compound **5** are caused by variations in the carboxyl group, $\nu_{as}(CO_2)$ and $\nu_s(CO_2)$.

In compound **7**, the strong intensity band at 2047 $cm^{-1}$ indicates the bond with the nitrogen atom of the isothiocyanate anion.

As a result of the interaction of zinc acetate with paoH in a 1:2 ratio in $CH_3OH$:DMF (5:1) medium, the non-electrolyte type complex $[Zn(CH_3COO)_2(paoH)_2]$ (**5**) was obtained (Figure 2.11) .

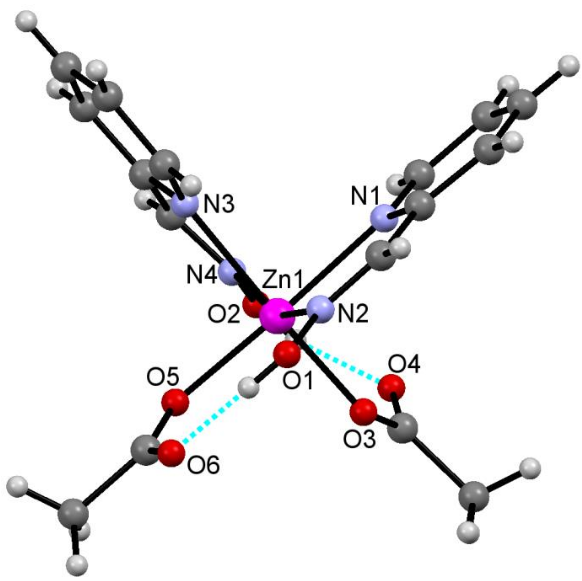


Figure 2.11. Molecular structure of the coordinating compound $[Zn(CH_3COO)_2(paoH)_2]$

The compound crystallizes in the monoclinic space group $P2_1/n$. The independent portion of the unit cell comprises the zinc cation, two acetate anions, and two paoH ligands.

The coordination polyhedron of the zinc atom is a distorted octahedron formed by a set of $N_4O_2$ donor atoms.

The zinc ion coordinates the chelate of two pyridine-2-aldoxime molecules through the pyridinic nitrogen atoms and the oxime group and two monodentately associated acetate ions to the complex generator through the oxygen atom of the carboxyl group. Each of the two coordinated paoH ligands forms a chelated pentacyclic ring with N-Zn-N endocyclic angles equal to 74.49(19) and 73.71(17)° and Zn-N distances in the range of 2.151(5)-2.262 (5) Å. In complex **5** the ligands are in the cis-position in mutually perpendicular planes, as indicated by the dihedral angle between the metal pentacycle equal to 89.07° (Figure 2.8). Two acetate anions coordinate monodentately to the metal atoms through O (3) and O (5), the Zn-O distances are 2.031(4) 2.044(5) Å, the O-Zn-O angle is 92.39(19)°. The oxygen atoms of the acetate anions not involved in coordination with the metal are involved in the formation of internal O-H···O hydrogen bonds with the oxime groups. Analysis of the Cambridge Structural Database provides clear evidence in favor of stabilization of the transition metal coordination polyhedron by two hydrogen bonds to the carboxylate anion in a number of mononuclear compounds and polymeric analogues of compound **5** [47].

In order to exclude the carboxylate anion from the complexation process, zinc tetrafluoroborate was used as the initial zinc salt, which easily yields the tetrafluoroborate anion. As a result of the interaction of $Zn(BF_4)_2 \cdot nH_2O$ with paoH in a 1:2 ratio in $CH_3OH$:DMSO (5:1) medium, an ionic complex $[Zn(paoH)_2(DMSO)_2][BF_4]_2$ (**6**) was obtained, built from the complex cations $[Zn(paoH)_2(DMSO)_2]^{2+}$ and the external $[BF_4]^-$ anions. The compound crystallizes in the monoclinic space group $P2_1/n$. The independent portion of the unit cell contains the zinc cation, two tetrafluoroborate anions, the two paoH ligands, and two DMSO molecules. The structure of the complex cation in compound **6** is similar to that in **5** with the replacement of two acetate anions by two DMSO molecules (Figure 2.12).

The paoH molecules form two chelated metallocycles, the Zn-N distances are in the range of 2.120(4)-2.293(5) Å, the N-Zn-N angles equal to 74.52(15) and 75.19(14)°. The Zn-O distances are equal to 2.091(3) and 2.052(3) Å. The absence of a stabilizing contribution of acetate anions results in a greater conformational freedom of coordination to the metal of the neutral ligands, evidenced by the inversion of one of the paoH ligands, somewhat shortening the dihedral angle between the metallocycles equal to 85.2°. $[BF_4]^-$ anions are retained in the crystal lattice by O-H···F hydrogen bonds.

In order to exclude the possibility of coordination of solvent molecules and with the aim of studying the anion exchange reaction, it was decided to introduce bidentate inorganic anions into the system, which could potentially occupy two coordination positions in the coordinated polyhedron of Zn(II).

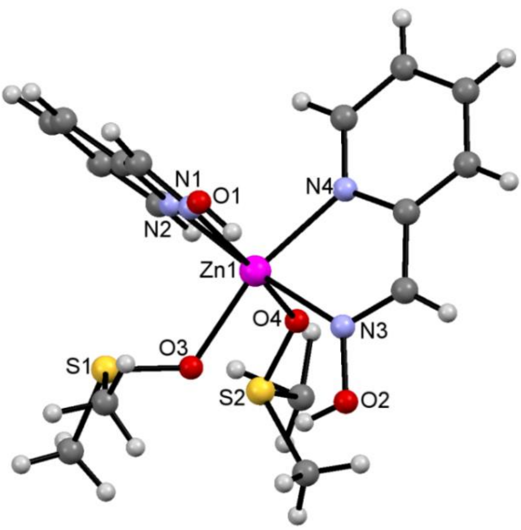


Figure 2.12. Structure of the complex cation $[Zn(paoH)_2(DMSO)_2]^{2+}$ in **6**

The use of ambidentate inorganic ligands, such as isothiocyanate, which have the ability to coordinate through two donor atoms, nitrogen and sulfur, pursued several goals: to investigate the possibility of coordination of thiocyanate anions to the atom generating the complex under competitive conditions with other potential ligands, to create conditions for the manifestation of this anion's bridging ligand properties, and to assemble coordination polymers.

As a result of the interaction of zinc tetrafluoroboratulium with paoH and $NH_4SCN$, a non-electrolyte mononuclear complex $[Zn(NCS)_2(paoH)_2]$ (**7**) was obtained. Compound **7** crystallizes in a C2/c centered monoclinic space group (Figure 2.13).

The neutral complex occupies a position on a two-fold axis, so that in an independent part of the unit cell are half a Zn(II) cation, a thiocyanate anion, and a paoH ligand. The coordination polyhedron of Zn (II) – octahedron $N_6$. The Zn-N distances are in the range of 2.045(4)-2.329(4) Å, the N-Zn-N endocyclic angle is equal to 73.25(14)°. In this sense, two paoH ligands are linked by a two-fold axis and are in the trans position, showing even greater *mobility*, the angle between the metallocycles being reduced to 79.61°. Unlike **5**, in **7** the intermolecular hydrogen bonds OH···S, in which a terminal sulfur atom of the NCS- anions participates, binds the molecules of the complex in infinite layers.

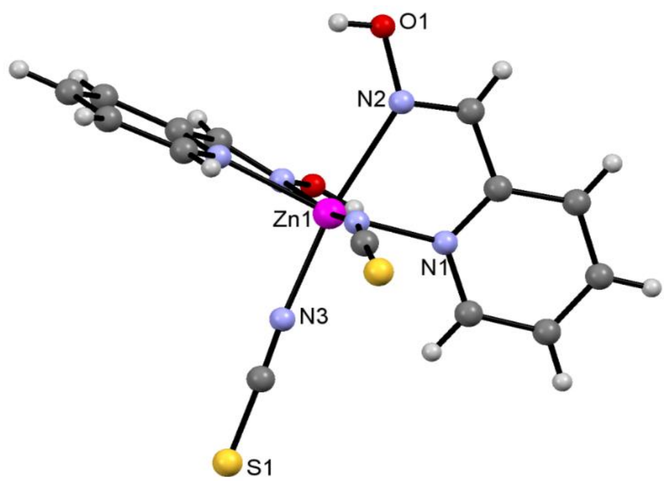


Figure 2.13. The molecule structure of the coordinating compound $[Zn(NCS)_2(paoH)_2]$

Thus, three new compounds are added to the structural diversity of monomolecular heteroligand complexes of Zn(II) with the pyridine-2-aldoxime chelating ligand, demonstrating a significant contribution of the second ligand (acetate, thiocyanate, DMSO) in the geometry of the metal's coordination polyhedron.

X-ray diffraction on single crystals for coordination compounds **1-2** and **5-7** was carried out at the Institute of Applied Physics' Laboratory of Physical Methods for the Study of Solids "T. I. Malinowski", Chisinau, Republic of Moldova.

*Biological testing*

In recent decades, a series of studies in the Republic of Moldova have been conducted, the results of which have been published in international journals with an impact factor and patented [48-53], in which the effects of the introduction of coordination compounds of some transition metals on physiological processes in some strains of fungi are described.

The biological properties of the tested complexes were evaluated based on their impact on the fermentation process of the micromycete *Aspergillus niger* CNMN FD 06, which is an active producer of amylolytic enzymes that hydrolyze starch-containing substrates under normal (pH 4.7) and extreme acidic pH conditions (pH 2.5).

Cultivation was done using the deep method on a medium with the previously chosen composition [54], medium pH – 5.0, cultivation temperature 28-30° C, constant agitation with a rotary shaker at 180-200 rpm.

The complex compounds were mixed with seeding material and added to a sterile nutrient medium at concentrations of 5, 10, and 15 mg/L. The medium that did not contain the complex compound served as a control medium. The complex compound's effect on the amylase activity of the micromycete *Aspergillus niger* CNMN FD 06 was measured over time on the fifth and sixth day of cultivation, which corresponds to the strain's maximum period of biosynthesis under traditional cultivation conditions.

Amylolytic activity was measured photocolorimetrically by determining the degree of cleavage of starch to dextrins of varying molecular mass under standard (pH 4.7) and extremely acidic (pH 2.5) conditions [29].

The biological tests were carried out in the Enzymology Laboratory of Institute of Microbiology and Biotechnology, Chisinau, Republic of Moldova.

*Biological research*

The compound $[Zn(CH_3COO)_2(paoH)_2]$ (**5**) was tested for its use in order to increase the amylolytic activity of the strain of a producer with biotechnological value – *Aspergillus niger* CNMN FD 06. The presence of the zinc atom in the composition of the complex, which is an essential micronutrient for microorganisms suggests that this substance may act on the physiological processes of the micromycete. The results showed that when the strain is grown under standard (control) conditions, the maximum activity of the standard enzyme (pH 4.7-50.68 u/ml), as well as the acid-stable ones (pH 2.5-56.56 u/ml) appears on the 5$^{th}$ day after cultivation. On the 6$^{th}$ day of cultivation, a sharp decrease was found in both types of amylase activity: 20.44 u/ml (pH 4.7) and 38.08 u/ml (pH 2.5) (Table 2.11).

Table 2.11. Modification of the enzymatic activity of the micromycete *Aspergillus niger* CNMN FD 06 amylases under the influence of the complex $[Zn(CH_3COO)_2(paoH)_2]$ (5)

| **Conc., mg/L** | **Standard amylase (pH 4.7)** | | | | **Acid stable amylases (pH 2.5)** | | | |
|---|---|---|---|---|---|---|---|---|
| | ***5th day*** | | ***6th day*** | | ***5th day*** | | ***6th day*** | |
| | ***u./ml*** | ***%*** | ***u./ml*** | ***%*** | ***u./ml*** | ***%*** | ***u./ml*** | ***%*** |
| **5** | 68.74 | **135.63** | 27.36 | **133.85** | 60.82 | 107.32 | 40.45 | 106.22 |
| **10** | 68.74 | **135.63** | 25.64 | 125.44 | 57.97 | 102.50 | 40.45 | 106.22 |
| **15** | 65.11 | 128.47 | 23.91 | 116.98 | 46.58 | 82.35 | 34.13 | 89.62 |
| **Control** | 50.68 | 100.0 | 20.44 | 100.0 | 56.56 | 100.0 | 38.08 | 100.0 |

The addition of the complex to the culture medium has a stimulatory effect, constituting 35.63% – 5 days and 33.85% – 6 days for the standard amylases and 7.32% and 6.22%, respectively, for the acid-stable ones. For amylases stable in an acidic environment, the stimulation effect is stable in the concentration range of 5-15 mg/L, being above the control level of the concentrations tested on both the 5$^{th}$ and 6$^{th}$ day. The stimulatory effect of acid-stable amylases is significantly lower and is manifested when using low concentrations of the complex – 5 mg/L. With increasing concentration, the effect becomes unstable and at a concentration of 15 mg/L it becomes negative. The addition of the complex to the cultivation medium of the strain does not affect the development phase of the micromycete and the amylase biosynthesis maximum occurs on the 5$^{th}$ day of cultivation and coincides with a maximum in the control variant.

Thus, it was found that the optimally selected concentration of 15-10 mg/L of zinc complex with pyridine-2-aldoxime $[Zn(CH_3COO)_2(paoH)_2]$ (**5**) can be used to stimulate the biosynthesis of standard amylases (pH 4.7) of the micromycete *Aspergillus niger* CNMN FD 06. The presence of the complex in the nutrient medium does not affect the duration of cultivation of the strain.

It has recently been established that complex combinations of transition metals play an important role in the processes that occur in living organisms, influencing their growth and development in both stimulating and inhibiting ways (antiviral, antibacterial, antitumor, etc.). They were found to have a stimulatory effect on the growth and productivity of a number of microalgae (*Spirulina platensis* (Nordst) Geitl and *Dunaliella salina* Teod.) for industrial cultivation, growth and rooting of various plants, and medicine preparation. They may also act as regulators of the biosynthesis of biologically active substances, such as extracellular enzymes, in a variety of microorganisms [48, 55].

The biological activity of some new metal coordination compounds is an important task in relation to their potential practical use, the identification of new applications. Understanding the fundamental role of the complex in the metabolism of living cells, as well as the causes of their increased biological activity, will provide a theoretical foundation for the deliberate synthesis of compounds with desired properties.

Compounds **3-5** were tested as potential biostimulators of amylolytic activity on the strain used – *Aspergillus niger* CNMN FD 06 – to investigate their potential influence on the physiological processes of microorganisms.

From a biological standpoint, the use of complex compounds is explained first and foremost by the fact that, as complexing atoms, they contain microelements, many of which (including zinc) are essential in small amounts for living organisms [56].

The results are shown in Table 2.12, and they reveal that the strain has the highest enzymatic activity of both standard amylases (50.68 u/ml – pH 4.7) and acid stable amylases (56.56 u/ml – pH 2.5) on the fifth day of cultivation. On the sixth day of cultivation, the activity of both types of amylases dropped dramatically: 20.44 u/ml (pH 4.7) and 38.08 u/ml (pH 2.5).

Table 2.12. Modification of the standard (pH 4.7) and acid stable (pH 2.5) amylase activity of micromycete *Aspergillus niger* 412 under the influence of complex zinc compounds with different ligands

| **Complex** | **conc., mg/L** | **Standard amylase (pH 4.7)** | | | | **Acid stable amylases (pH 2.5)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***5 days*** | | ***6 days*** | | ***5 days*** | | ***6 days*** | |
| | | ***u/ml*** | ***%*** | ***u/ml*** | ***%*** | ***u/ml*** | ***%*** | ***u/ml*** | ***%*** |
| **3** | 5 | 76.01 | **149.98** | 29.09 | 142.32 | 66.53 | **117.63** | 37.16 | 97.58 |
| | 10 | 65.11 | 128.47 | 29.09 | 142.32 | 52.29 | 92.45 | 27.82 | 73.06 |
| | 15 | 65.11 | 128.47 | 27.36 | 133.85 | 52.29 | 92.45 | 26.24 | 68.91 |
| **4** | 5 | 79.64 | **157.14** | 32.55 | **159.24** | 66.53 | **117.63** | 38.87 | 102.07 |
| | 10 | 70.56 | 139.22 | 27.36 | 133.85 | 49.43 | 87.39 | 37.16 | 97.58 |
| | 15 | 66.92 | 132.05 | 27.36 | 133.85 | 46.59 | 82.37 | 30.97 | 81.33 |
| **5** | 5 | 72.37 | **142.79** | 29.09 | 142.32 | 63.67 | **112.57** | 37.16 | 97.58 |
| | 10 | 68.74 | 135.63 | 29.09 | 142.32 | 63.67 | **112.57** | 30.97 | 81.33 |
| | 15 | 57.84 | 114.13 | 25.64 | 125.44 | 43.74 | 77.33 | 27.82 | 73.06 |
| Control | - | 50.68 | 100.0 | 20.44 | 100.0 | 56.56 | 100.0 | 38.08 | 100.0 |

Further analysis of the findings reveals that the strain under consideration is sensitive to the addition of complex zinc compounds to the cultivation medium. At a pH of 4.7, their impact on the enzymatic activity of amylases, which hydrolyze starch-containing products, was particularly noticeable. Their activity in the optimized media is significantly higher than in the control media. When the zinc complex with isonicotinamide (4) was used, for example, the enzyme activity in the experimental variant was 79.64 u/ml, 70.56 u/ml, and 66.92 u/ml depending on concentration, compared to 50.68 u/ml in the control.

According to the effectiveness of the impact of the substance, compounds **3-5** is approximately the same. The optimal concentration can be considered equal to 5 mg/L, providing a high stimulatory effect – 42.79-57.14% (5 days of cultivation). On the $6^{th}$ day the stimulatory effect remains approximately at the same level and is 42.32-59.24% compared to the control.

The effects of the tested compounds on the activity of acid-stable amylases were less effective. The stimulatory effect, as in the case of unstable amylases in an acid environment, manifests itself on the $5^{th}$ day of cultivation at the same concentration – 5 mg/L and constitutes 17.63% (**3**), 17.63% (**4**) 12, 57% (**5**). Thus, the testing of complex zinc compounds with different ligands revealed that the optimally chosen concentration of 5 mg/L can be used to stimulate the biosynthesis of the amylases of the micromycete *Aspergillus niger* CNMN FD 06, both in the standard ones – 57.14% (pH 4.7), as well as 17.63% acid-stable (pH 2.5).

Thus, activity in various forms of research-based training creates favorable conditions for activity in new circumstances, with an inter- and transdisciplinary character, and contributes to the development of the chemical student's professional skills, particularly research competence.

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# CHAPTER 3. EXPERIMENTAL ARGUMENTS REGARDING THE EFFICIENCY OF THE DIDACTIC TECHNOLOGY OF VOCATIONAL TRAINING OF THE RESEARCH COMPETENCE OF STUDENTS FROM THE FACULTY OF BIOLOGY AND CHEMISTRY IN AN INTERDISCIPLINARY CONTEXT

The advancement of chemistry didactics from the perspective of instructional approaches oriented toward the formation of research culture inevitably leads to the revelation that higher education is close to some serious determinations regarding the evaluation and continuous development of investigative competences. The current requirements of policy documents regarding research and innovation in professional education are highly valued in higher education. In this regard, global trends encourage the idea of rethinking university curricula in order to contribute to the continuous development of research competences. The experimental study, when applied to chemical students, provides their professional training system with valuable ideas, action models, and knowledge styles via research-innovation-entrepreneurship, which are the current desires for scientific judgment in the spirit of the times. The chemistry didactics is looking for optimal models of integration of theoretical training for knowledge and practical training, for the validation of professional competences derived from extensive research. Current university didactic trends reflect increased efforts by teaching staff to broaden the use of research-oriented pedagogical strategies for the development of learning structures in students through research and independent study, exceeding the limits of some optimistic expectations recorded in educational history.

Why has research-based instruction become the major challenge of postmodern didactics?

For these reasons, reconsidering the recommended university didactic technologies in chemistry teaching-learning-evaluation is a problem of maximum concentration, the disciplinary picture in a strategic plan, requiring new knowledge, not only from the area of chemistry didactics, but also from the related fundamental fields: educational management, curriculum theory, instructional theory, learning theories, and evaluation theory. Higher education institutions trained in innovative teaching-learning-evaluation experimentation programs, managing, and promoting the quality of used didactic technologies, will have a bright future. Throughout the socio-professional life, the higher school seeks to identify and develop self-directed learning structures with adaptable and effective pathways in professional contexts.

## 3.1. PRELIMINARY STUDY OF THE STUDENT REPRESENTATIONS FROM THE FACULTY OF BIOLOGY AND CHEMISTRY REGARDING THE PROFESSIONAL COMPETENCES AND THE IMPORTANCE OF THE PROFESSIONAL TRAINING FOR THE RESEARCH AND INNOVATION IN EDUCATION

As an echo of the labor market demands for creative specialists, the current university policy in promoting research culture advances constant rigors regarding the continuous adaptation of university training to the changing professional training needs of students. According to this viewpoint, the effectiveness of teaching-learning-evaluation depends on the effective behavior of university teaching staff and students' learning motivation through research, which is determined by their professional thinking flexibility. In order to achieve the proposed objectives, the study was carried out on an experimental lot of 228 students from the first (102) and second (126) cycles of the Tiraspol State University.

The findings of an interview with students from the Faculty of Biology and Chemistry, Tiraspol State University (126 respondents, second-cycle students) about the importance of professional training for research and educational innovation are intriguing (Figure 3.1).

We are impressed that most students (61.3 % – medium and 37.1 % – advanced) believe that research and innovation are processes inherent in the professional training of teachers and educated people, respectively, while only 1.6 % are unsure.

Starting with the idea that the effectiveness of professional training is a human attribute, in order to be effective, students must demonstrate: personal integrity, rationality, the clarity of formulating professional priorities, adaptability to change and openness to new things, consistency in decisions and autonomous professional development initiatives, high level of participation and integration, maximum focus on learning through research and deep motivation for the learning activity, power of will and capacity to use time rationally, creativity and energy in prioritizing learning, synergy and productivity in experimenting with new acquired knowledge.

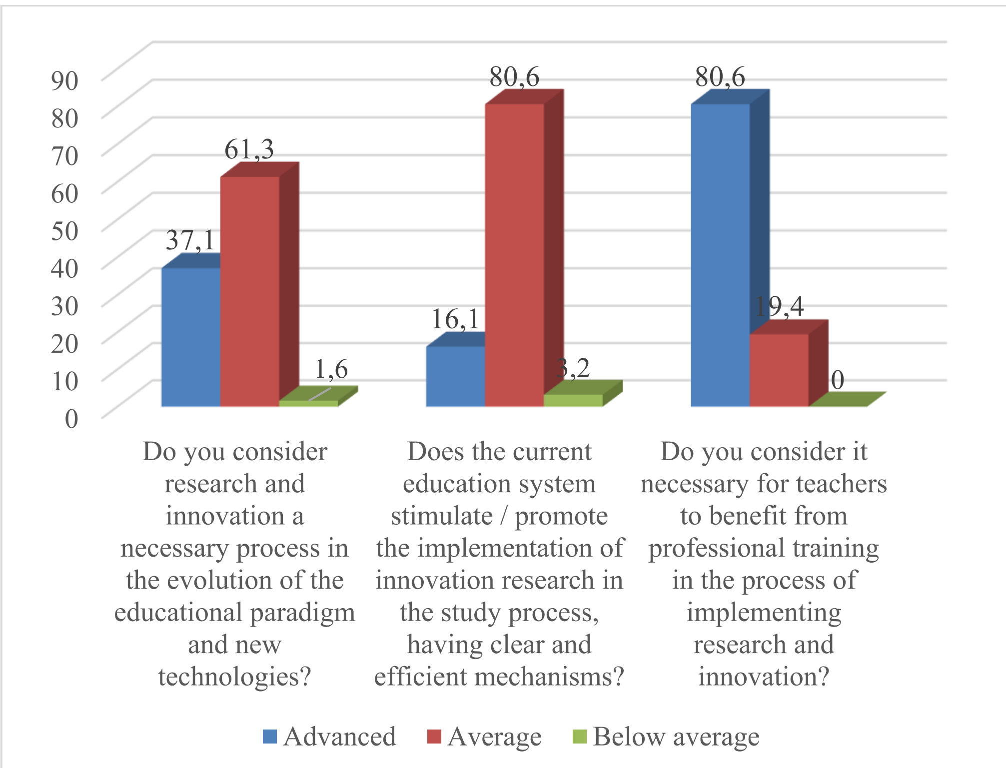


Figure 3.1. Student representations on the importance of research and innovation in the evolution of the education paradigm (%)

The characteristics of efficient and motivated students for research-based learning highlighted in pedagogical research result from their perception of professional roles formulated from the perspective of current demands in relation to the teaching profession (Figure 3.2).

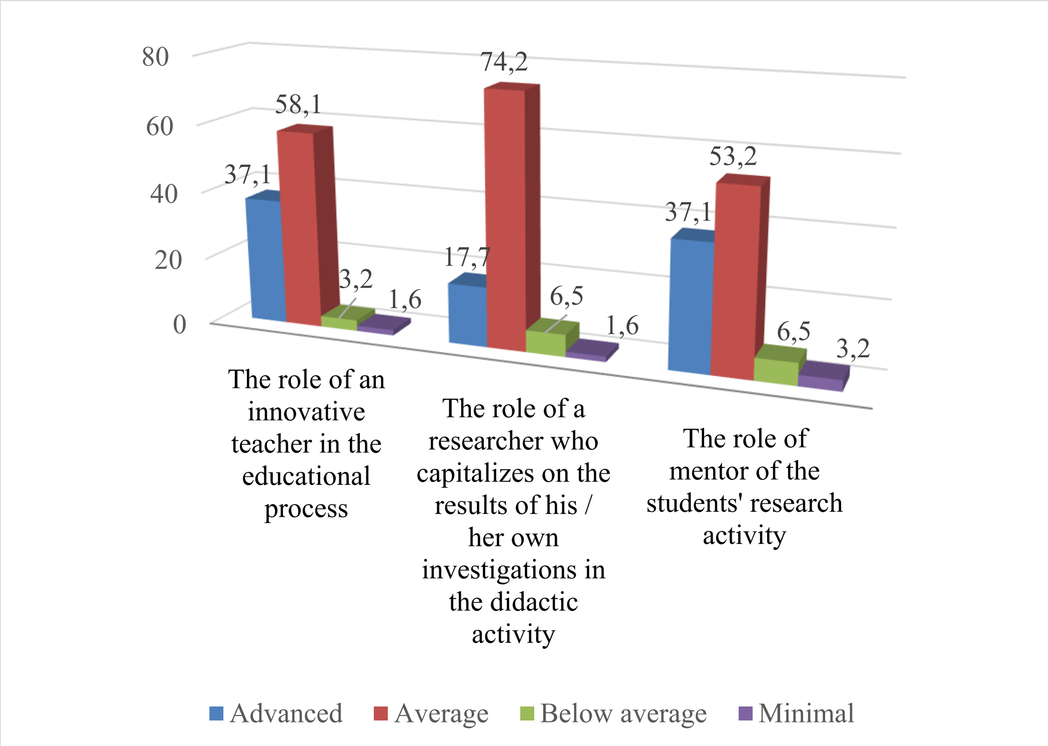


Figure 3.2. Students' perception of the professional roles that determine the formation of research competence in the initial professional training process (%)

According to students, the main professional roles of university teachers, as reflected in Figure 3.2, are: the role of innovative teacher (58.1% - medium and 37.1% – advanced, with only 4.8% being insufficiently convinced in this meaning), because, as they stated, "professional efficiency and effectiveness" are a result of reporting to the responsibilities, conditions, and perspectives of professional development; of documentation and scientific research, critical and constructive reading; of the use of constructive strategies, of the valorization of the methodology of conception, organization, management of student research projects in a systemic, experimental, interdisciplinary, applicative vision, pedagogical actions that would essentially contribute to the formation of competences for the full exploitation of the investigative potential and would facilitate the rational use of time for continuous professional development.

It's interesting to see how the students intuitively understand the role of a researcher who uses the results of their own investigations in the didactic activity, appreciating primarily with (mean – 74.2% and high – 17.7%). This is explained by students' lack of understanding of the research function of the teaching staff. The importance and high appreciation of the mentoring role of the students' research activity is noted (high – 37.1%, mean – 53.2%). The minimum – 3.2% and below average – 6.5% appreciation of this professional role also demonstrates the students' poor training in research activity, demonstrating the opportunity to amplify the tenacious design efforts of university didactic activities based on research training strategies.

Chemistry didactics provides the opportunity for a dual formative project: didactic modeling of learning experiences through research on the one hand, and modeling of students' cognitive structures on the other. The challenges of didactic competences are becoming more pronounced in this approach.

Most students believe that the development of research competence is a requirement of today's knowledge-based society, and that as a result, the process of developing this competence should begin as early as possible: the most considered – primary education (41.9%), with the period of preschool education highlighted (32.3%). Despite difficulties in determining the age at which, according to curricular provisions, the development of research competence in children begins, the students' experimental data show the correct estimate and are close to the results of the previous question. Thus, they emphasized (primary education – 40.3% of the subjects and preschool education – 16.1%), demonstrating students' deep awareness of the critical need to form scientific knowledge capacities for elementary school students as early as possible through research-oriented education (Figure 3.3).

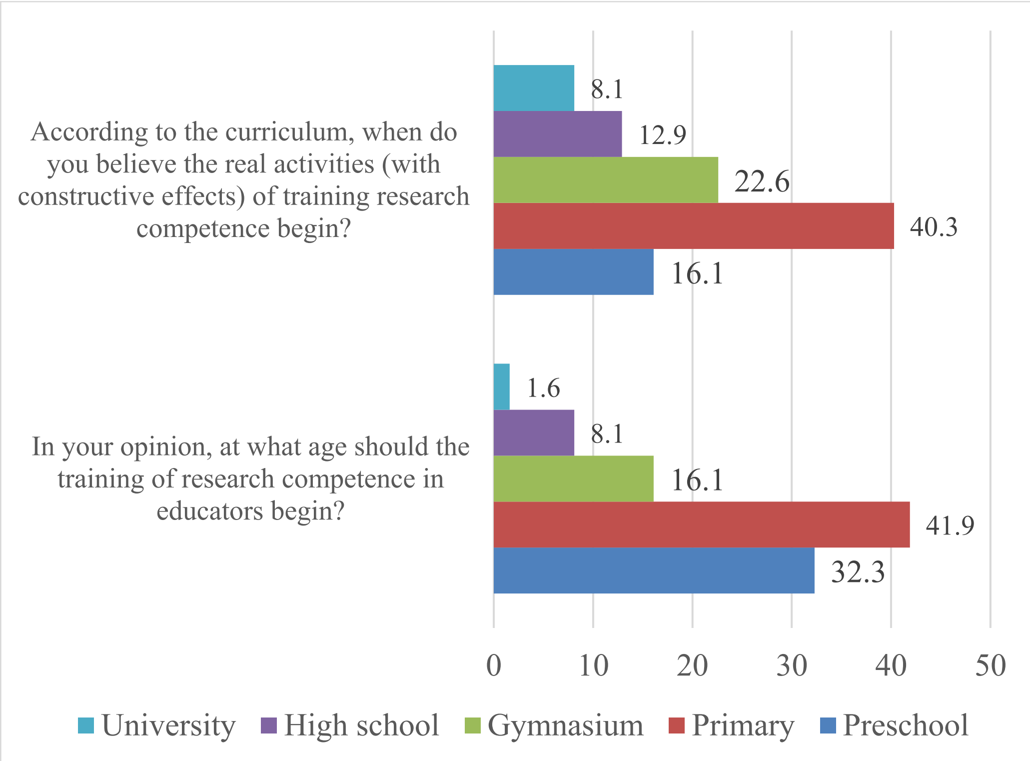


Figure 3.3. Students' opinion about the age of curricular debut in the formation of research competence (%)

Another scientific interest in the experimental research was to find some answers to the question: What is the degree of formation of professional research competence in students?

The investigated students demonstrated a strong interest in and motivation for research (advanced level of motivation – 35.5% and medium level of motivation – 62.9%). The results of the survey on the degree of innovation of the professional learning activity (66.1% for the average level and 21.0% for the high level) are generators of pedagogical reflections; however, some students rated this professional competence as below average formed – 12.9% (Figure 3.4).

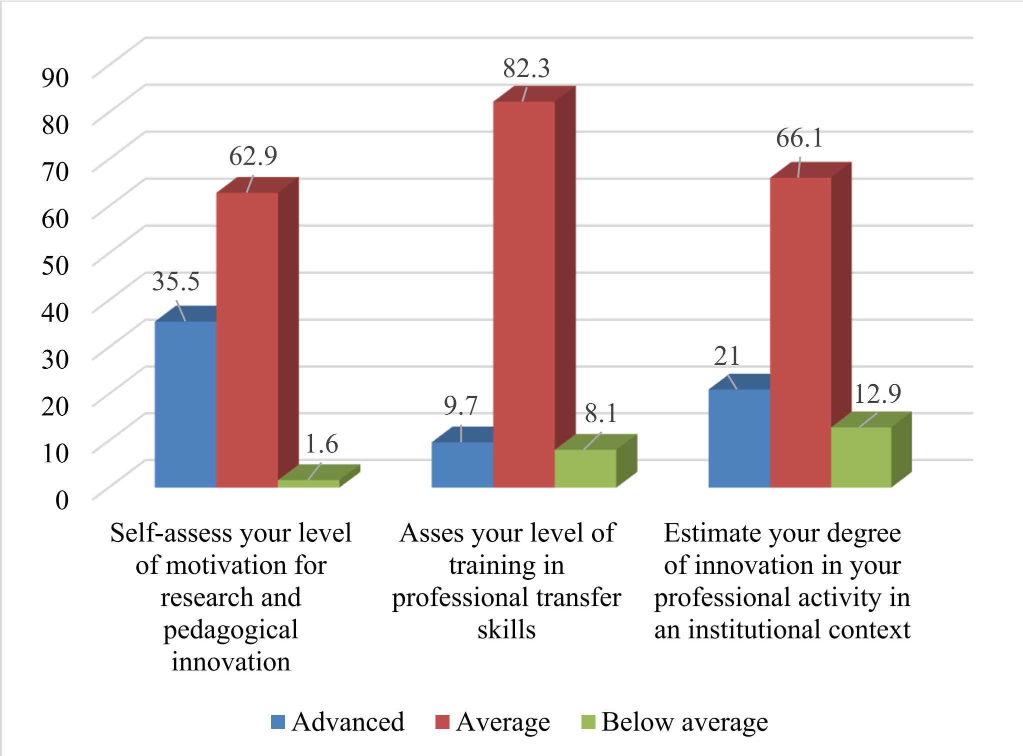


Figure 3.4. Motivation for research and training levels of research and innovation competence estimated by students through self-assessment (%)

The interpretation of the answers to these questions were formulated by combining some conclusions generated by theoretical analyzes and experimental data.

The balanced distribution of experimental data between the reasons proposed to students for their choice indicates that they have the correct perception of professional needs for career advancement through research activity.

It has been discovered that the need to train students' research competences is determined by contemporary social challenges and results from the content of research-based learning experiences, the quality of relationships between university teachers and students, and their research motivation strategies for the learning activity self-directed, self-instructional, incentivized, and incentivized/fueled long-term.

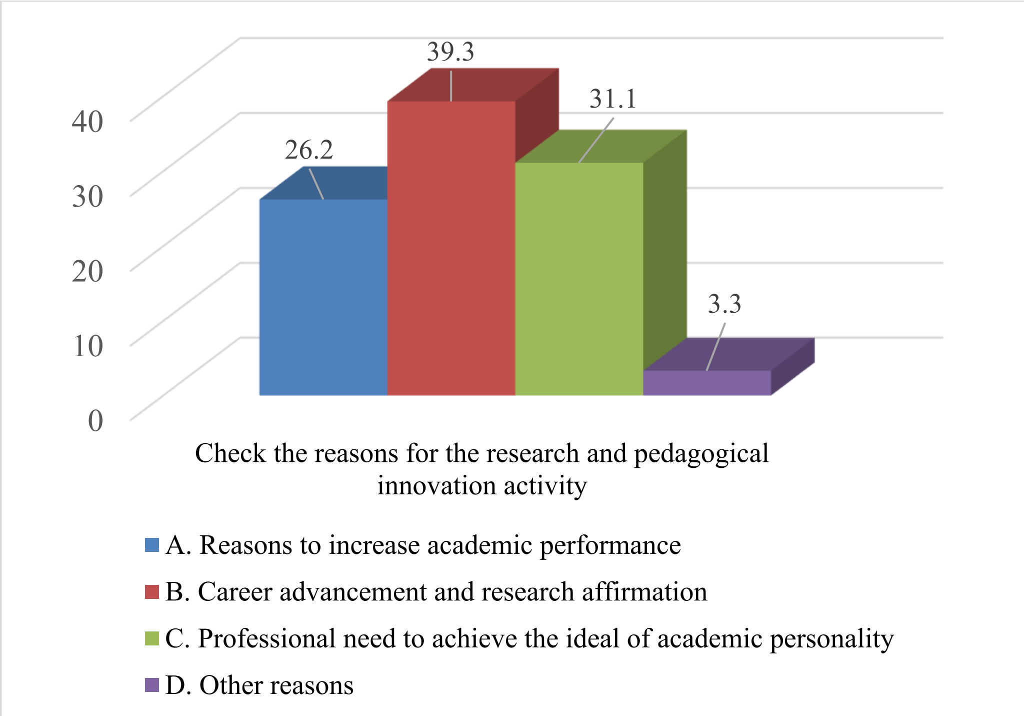


Figure 3.5. Relevant reasons for increasing academic performance through student learning through research (%)

This three-dimensional integration: research-based pedagogical action, socio-professional life demands, and investigative and entrepreneurial competences, defines the theoretical and practical significance of chemistry didactics today.

The analysis of the experimental data reveals the multiplicity and concurrent nature of professional responsibilities, which creates obvious barriers in the design and implementation of professional research (48.4%). For these reasons, the mission of modern universities is to start preparing students to develop research projects, obtain new information, and act in an innovative manner. Students today must learn what it means to know (i.e., possess knowledge), to be able to do (express abilities), and to be competent (demonstrating attitudes). They recognize the need for additional professional research methodology training (22.6%) as well as insufficient knowledge of research mechanisms (27.4%).

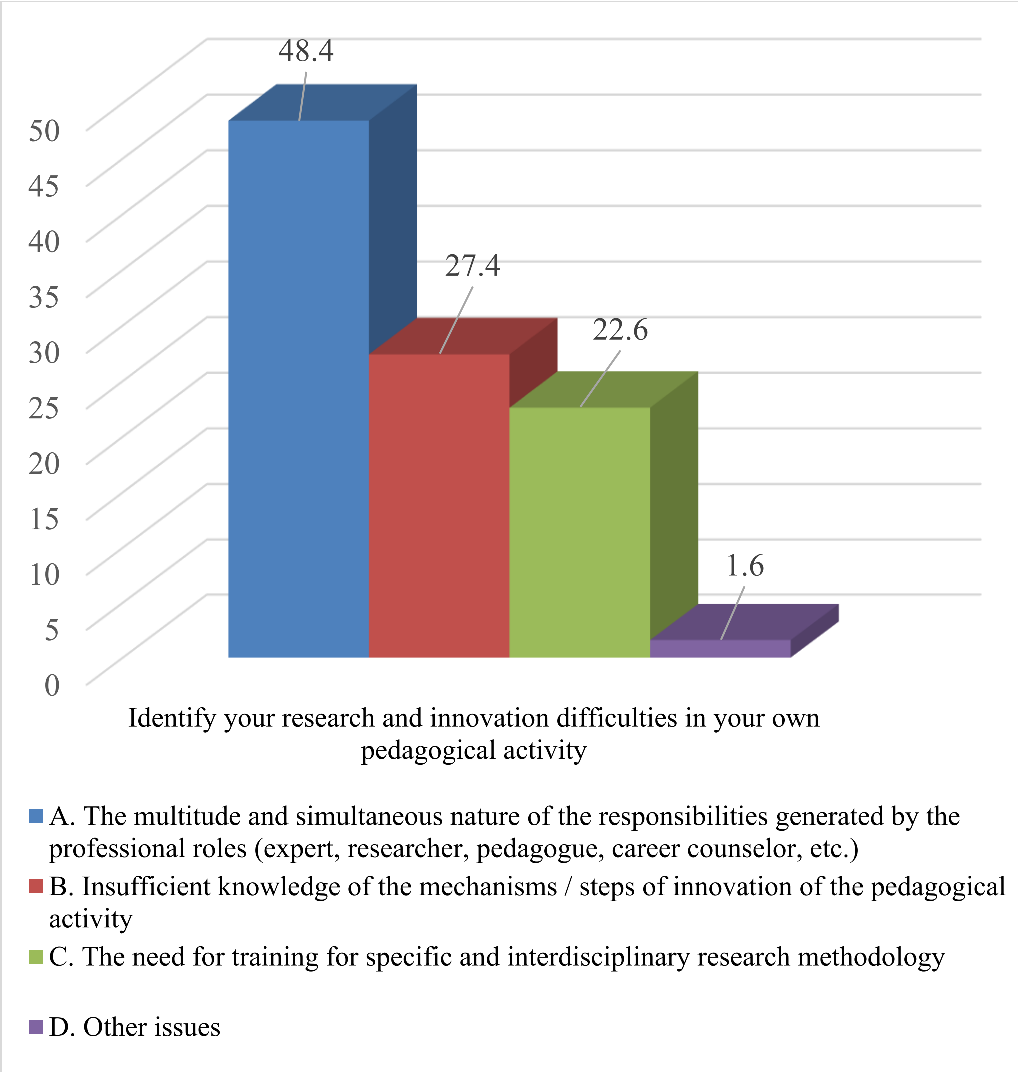


Figure 3.6. The problems that students face in professional research (%)

Figure 3.7 depicts the availability of students for research activities via various modules, disciplines, organizational forms, and university didactic strategies. Attractive are the findings that show students' predisposition to learn qualitative research methodology specific to their field to improve their research competences (promotion of research culture – 61.3%, education for research – 59.7%). There is a lack of understanding of the scientific spirit of the technology transfer concept (16.1%).

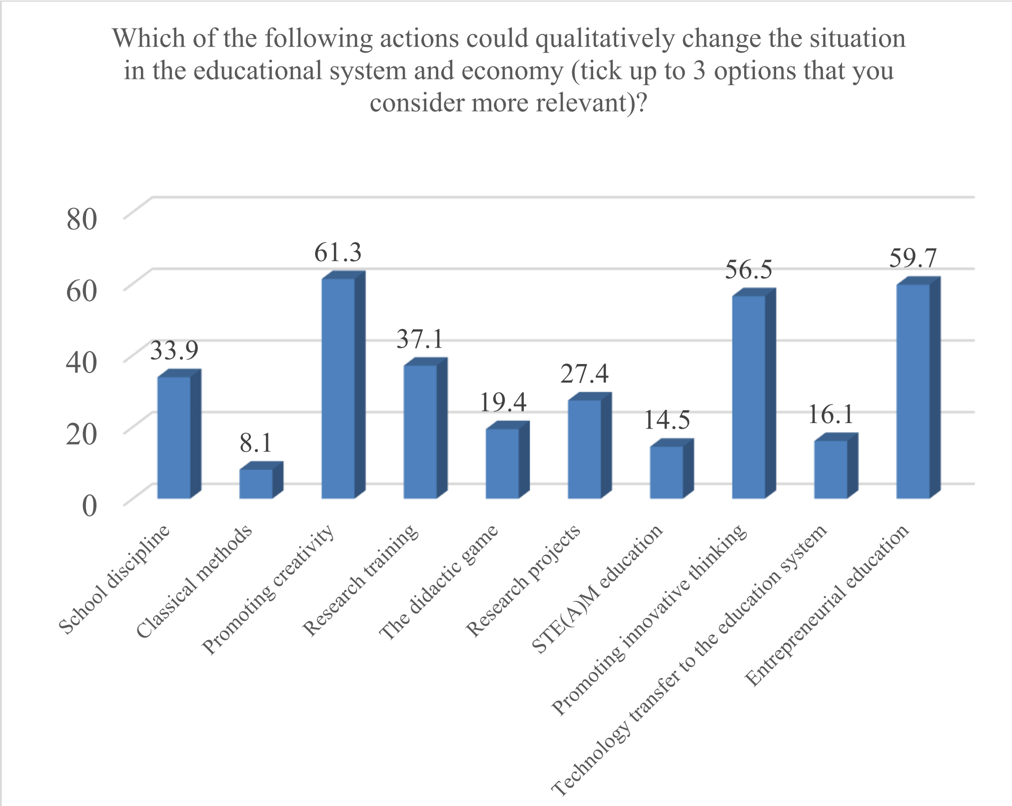


Figure 3.7. Actions that would produce qualitative changes in the direction of training research competences in students (%)

The pedagogical experiment was designed and carried out in stages to establish the attitude of chemistry students from the first cycle toward the possibility of training professional competences within the interdisciplinary course *Chemistry for Life – Integrated Research*. The following pedagogical experiment objectives were established in accordance with the research purpose:

- ascertaining the attitude and expectations of chemical students toward the opportunity to promote the interdisciplinary course *Chemistry for Life – Integrated Research*;
- determining the initial level of training of chemical students' specific competences in the professional field (stage of establishing the experiment).

The questioning method was used in the context of experimental research to meet the needs of the investigation. In this context, a questionnaire was created and distributed to 102 students in their first and second years of study from the specialties of Chemistry, Chemistry and Biology, Biology and Chemistry (full-time), and Chemistry (part-time). The questionnaire was composed of ten items. Following that, we will present the most important results from the experiment in terms of the scientific significance of professional competences in general and research competences in particular.

The scientific meanings of the term in question identified by chemistry students in their answers to ***Item 1. "Define the notion of professional competence".*** Based on the analysis of the students' responses, we discover multidisciplinary approaches to professional competence, which are reflected in the large number of outlined meanings. Table 3.1 displays the students' answers to this item.

Table 3.1. The scientific significance of the professional competences specific to the students of the Faculty of Biology and Chemistry

| Number of people | Full answer of definition | | Partial answer of definition | | Incorrect answer of definition | |
|---|---|---|---|---|---|---|
| | Students, no. | Share, % | Students, no. | Share, % | Students, no. | Share, % |
| **102** | 34 | **33.33** | 43 | **42.16** | 25 | **24.51** |

We conclude from the answers presented by the students that *professional competence* has a variety of dimensions that converge on the idea that, in general, competence represents sets of *structured knowledge*, *capacities*, and *attitudes*. Among all the definitions, the students highlighted the *capacities* component, which is the basis of professional conduct, in the conditions in which they are practiced systematically and progressively in certain situations of learning a profession, as particularly important.

Table 3.1 demonstrates that the respondents (102 chemistry students) held diverse views on the definitions of professional competence. Only 33.33% of students provided complete definitions of competence, 42.16% provided incomplete definitions, and 24.51% provided uncertain answers. Students frequently misunderstand the definition of professional competence and invoke its elements. They correctly define the following terms based on those stated: the capacity to apply, transfer, and combine knowledge and skills in a variety of situations and work environments, the capabilities of a specialist in a specific field, and so on.

Theoretical and applied research on teacher education also reveals novel opportunities for professional development. We notice similar elements of professional competence when we analyze the concepts of professional training in various education systems around the world. Regardless of the paradigm that underpins them (humanistic, with an emphasis on the integral development of the personality), there are common, identifiable dimensions in the training concepts that propose to cultivate them (specific abilities – pragmatic, centered on the acquisition of some algorithms, rules of action with immediate practical relevance). Competence is defined primarily by three types of acquisitions: knowledge, capacities, and attitudes. Representatives of this orientation make competence the finality of the training program, defining competence as conduct that is supposed to promote the success of students' learning. Specialist training in any field is organized around the conceptualization of the training program based on professional competences.

**On item 2, "*List elements (components) of professional competence*",** chemistry students' responses demonstrated their specific knowledge that "competence appears as a distinct learning result, distinct from knowledge and abilities". It is found that the concept of knowledge and abilities integration in the competence structure does not appear explicitly in the responses elicited by the responding students. The students listed various types of competences in relation to the roles, tasks, and problematic situations to be solved, which are depicted in Figure 3.8.

The elements of professional competence listed by chemical students as required to carry out a didactic activity that contribute to the achievement of the proposed objectives differ. The competences for the teaching profession are systemic, and they are integrated with the general competences for the effective performance of some social roles. The theoretical and practical concepts required for professional activity are constantly evolving and are dependent on how students acquire them.

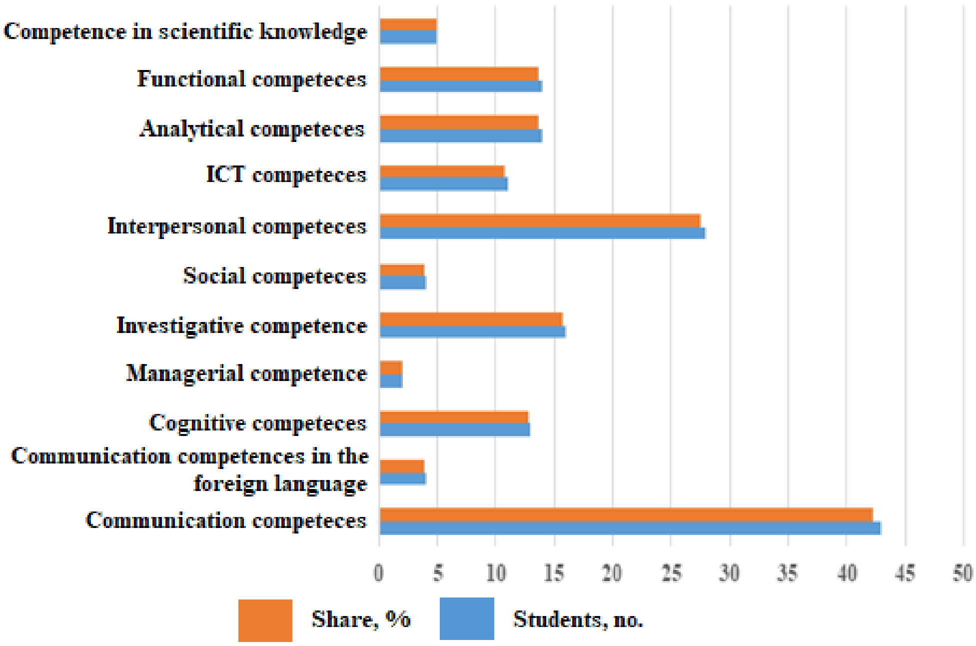


Figure 3.8. The share of the elements in professional competence.

The principles and criteria underlying professional competence formation refer to levels reflected in structures and indicators of general competences and specific competences aimed at:

a. understanding and adequate operational use of profession-specific concepts;
b. interpretation of ideas, concepts, models, and paradigms in the field;
c. designing, managing and evaluating learning activities, using coherent methods, techniques and tools for self-knowledge and professional reflexivity;

d. critical and evaluative-constructive thinking of some projects, processes and phenomena present in educational theory and practice, in solving problems in the professional field;
e. capitalizing on strategies facilitating creative-innovative behavior in the field of the profession.

Chemistry students' professional integration is a complex process of capitalizing on specific professional knowledge, capacities and convictions, creativity, and professional imagination. The current impact of technological progress necessitates the development of research, reflective, and creative capacities. As a result, there is a constant need for professional (self) development. Rethinking university didactic strategies must be oriented toward determining a set of changes ranked in the short, medium, and long term in relation to professional training priorities at the level of professional standards.

The chemistry students' answers to **Item 3.** ***"Present examples of professional competences formed during the Chemistry Didactics classes"*** were clear and meaningful. The Didactics of Chemistry study opens up possibilities for fundamental acquisitions and has a practical function, guiding the concrete didactic activity based on some general guidelines, contributing to the formation of specific designed competences. Chemistry didactics' specific methodologies train interdisciplinary and intradisciplinary contents, bringing precise specifications in adapting the requirements of the purposes, content, methods and procedures, organizational forms, design, and evaluation strategies. Thus, the training concept enables the development of a link between initial training and professional development activities to integrate and adapt chemical students to professional realities. As in any other field, the problem of a professional profile arises in education by referring to certain standards specific to this profession, with the phrase professionalization for a career being used more and more lately. According to the field's authors, the phrase "to be a teacher" must be understood in the sense of "becoming a teacher", which means transforming a job into a career, because the activity performed by a teacher is one of the most complex among the various activities, characterized by instrumental dimensions as well as deeply human dimensions, as revealed by the set of values that the teacher expresses in the educational space. In conclusion, the researchers' plea for behaviorist-inspired teacher training models becomes clear, advocating for training based on competence, performance, and the exercise of specific roles that facilitate the affirmation of teachers through the success of the student's learning. Table 3.2 and Figure 3.9 show the types of competences demonstrated by students in the Didactics of Chemistry subject.

Table 3.2. Types of competences formed during the classes in Chemistry Didactics

| Competences formed during the classes in Didactics of Chemistry | Students, no. | Share, % |
|---|---|---|
| **Communicative competence** | **38** | **37.25** |
| Epistemological competence | 6 | 5.88 |
| Metacognitive competence | 11 | 10.78 |
| Analysis and synthesis competences | 11 | 10.78 |
| **Competence in investigation / experimental research of chemical substances and processes** | **41** | **40.2** |
| Scientific competence | 5 | 4.9 |
| ICT competence | 7 | 6.86 |
| **Analytical competence** | **16** | **15.69** |
| Functional competence | 14 | 13.72 |

Because the primary concern of university education is the development of articulated responses to contemporary challenges that generate tensions in public policies in general and educational policies in particular, the teacher is required to make decisions that correspond to the values socio-professionals invoked by the problem of humanity. The fact that this also refers to the Western European world, where the roles of nations in the world's major conflicts are being reconsidered, is paradoxical. The fact that this also refers to the Western European world, where the roles of nations in the world's major conflicts are being reconsidered, is paradoxical. In these circumstances, society imposes new requirements on the personality during training, correspondingly new roles, and professional competences of the teaching staff, which, in fact, constitute a socio-pedagogical product with a distinct character and include a plethora of capacities with open psychological valences, always improvable in response to political, economic, and cultural changes.

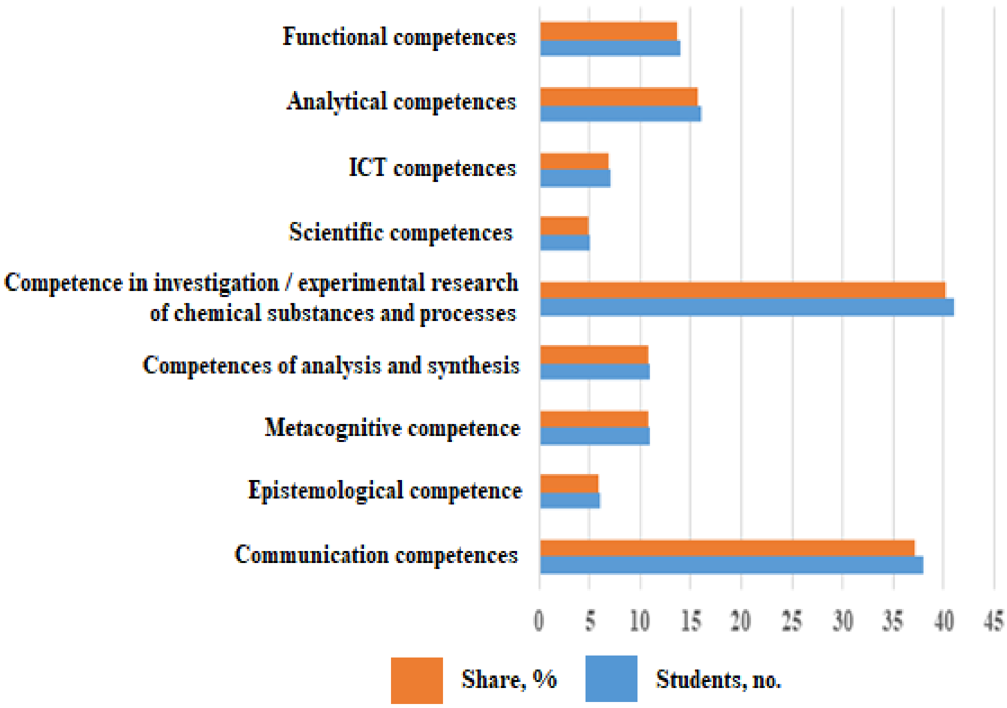


Figure 3.9. The share of the types of competences formed during the classes in Chemistry Didactics

The present reality clearly shows that the most effective solutions can be found through systemic approaches and a generalizing vision in studying the professional profile of the teaching staff's personality, specifically the pedagogical specificity from the perspective of chemistry didactics.

**In item 4, *"Define the elements of professional competences specific to chemistry didactics",*** it is discovered that chemical students identify the elements of professional competence: knowledge-capacities-attitudes are subject to moral and customary erosion to a greater extent than general competences. Oscillations are observed in the formation of students' representations of the meanings assigned to competences. This phenomenon is also explained by current trends in higher education of renovating the pedagogical curriculum based on competences, which has become a constant concern in the last decade. The curricular reform-driven strategic resizing of the university professional training process introduces new requirements for the professional reference of teaching staff and emphasizes the importance of actively promoting a research culture. Because of the unpredictability of educational changes, behavioral indices based on teachers' professional responsibility are required. From this perspective, professional standards will be open to some restructuring, with a focus on a set of competences that round out teachers' professional profiles and serve as the basis for evaluating their qualifications. Table 3.3 displays the survey results related to the elements of professional competences.

Table 3.3. Opinions of chemistry students on the components of professional competences

| Components of professional competence | Students, no. | Share, % |
|---|---|---|
| Knowledge | 39 | 38.23 |
| Capacities | 60 | 58.82 |
| Attitudes | 35 | 34.31 |

Most students indicated the three components of professional competence in their responses. Professional competence has characteristics in the fields of educational traditions, as well as dimensions that complete it. This consists of a totality of cognitive, affective, and motivational capacities that, when combined with his personal characteristics, gave him certain qualities required to carry out a teaching profession that ensures the learners' achievement of the designed objectives and generates intellectual and professional performances. These competences are based on the capacity to apply, transfer, and combine knowledge and skills in a variety of situations and environments to carry out activities in educational institutions at the standard's specified quality level.

Professional competence, on the other hand, is a necessary ability for a profession/group of related professions that manifests and develops within the professional framework. It is not a finished product, like any other type of competence, but a dynamic personal value that can be extended to a higher level of training.

The data (58.82 % of chemical students) show a recognition of the practical importance of professional competences (the *capacity* component is fundamental in their development). It engages in the effective capitalization of capacities in the qualitative differentiation of influences exerted on objective and subjective processes in the domain of education, acting coherently and consistently at the level of a specialist model with a professional reference marked by the characteristics of integrity, professional adaptability to innovative changes in educational area.

The original perceptions evoked by chemistry students' responses to **Item 5, *"List characteristics/roles of the modern chemistry teacher",*** were found to be impressive. The teaching staff's professional roles specifically refer to the essential characteristics for effective teaching activity. These roles indicate directions for teacher training in accordance with the challenges, demands, and obligations, based on a set of values, beliefs, and abilities/capacities for teachers' decisions and actions in their professional activity that define and facilitate chemistry students' self-directed learning process. From the perspective of pedagogical research, the functional coexistence of the laws of the development of self-instruction competence is recorded: (*a*) the law of motivation, which reflects the energy-generating action, of supporting the pace of learning through external and/or internal resources/impulses, of selecting priorities, of rationalizing the efforts and time allocated, to overcome obstacles, barriers, frustrations, dissatisfaction and dependencies, to facilitate the internalization of the values of academic learning; (*b*) the law of inverse connection which ensures the regularity and power of action of feedback, the consistency of correct representations/reference images, the quality of achieving progress, of success versus non-achievement, failures and errors, configuring, as a consequence, solutions, interventions, corrections, improvements; (*c*) the law of repetition – explanatory for the logic, frequency, type and nature of exercises to resume/reiterate learning; (*d*) the law of transfer, applicable and explanatory for the creation of positive mobility, the quality of transformative or accelerated learning. The emphasis on educators/students reflects modern didactics' orientation toward the formation of self-instructional competence, a tempting but complex and difficult subject referring to the development of intellectual and cognitive capacities, individual work capacities, personal reflection, critical, active, and creative spirit, their training in searches and discoveries, analysis and comments, training by action, the valorization of knowledge experiences, the highlighting of knowledge experiences, and the foregrounding of knowledge experiences, the formation of the transfer capacities of the new knowledge accumulated from the activity of scientific and empirical cognition (the process of knowing) and the management of self-instructional efforts in various learning situations.

Based on the work Education in change by Andre de Peretti [1], we analyzed the answers to this item. The author, considering the functions of the school and the teacher's mission, thinks the following professional roles are important:

I. person-resource, instructor and guide (teaching-learning-evaluation act expert);
II. responsible for interpersonal relations, organizer and manager of communication;
III. technician, establishing learning situations or making audio-visual and IT

productions, individual and collective, with multiple materials (ICT user);

IV. evaluator, on the one hand method advisor and on the other hand controller of progress;

V. researcher, director of individual study and investigation projects, as mediator of relations with the outside world.

Figure 3.10 summarizes student responses to chemistry teacher characteristics.

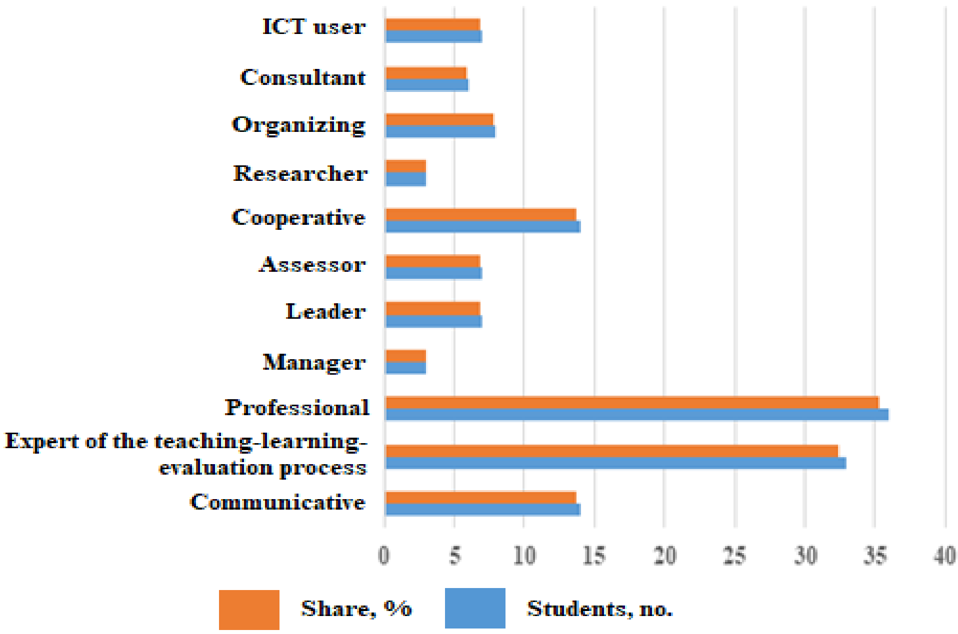


Figure 3.10. Relevant characteristics of the chemistry teacher

Based on the previous statements, we conclude that the roles of modern teaching staff are focused on the following main dimensions of professional activity: resource person, relationship manager, researcher, and evaluator, each with distinct characteristics and underwriting specific competence units for professional competences.

In the item regarding the roles of the chemistry teacher, the students highlighted the following:

I. resource person, most students, 67.64% noted the role of a professional - instructor and guide in documentation. They believed that the role of the modern teacher is to train the human personality. Sequences from the answers: “to form skills and abilities to integrate into society; to contribute to personality formation; to educate the child according to society’s requirements; to instruct the student in such a way that he is able to acquire; to provide society with smart people to be proud of; to instill in students a love for books, to form in students a correct behavior in society; to prepare students for integration into society; to ensure an efficient educational process; to teach them, to guide the children; to show them the way to success; to transmit knowledge; to integrate them into social life; to offer new knowledge and skills, etc.”;

II. 13.72% appreciate the teacher’s role of being cooperative in the chemistry training process;

III. 7.84% highlight the role of organizer of the modern chemistry teacher, responsible for interpersonal relations, animator. The students state: “to motivate the students for various types of activities, to be understanding, to integrate them in group activities, to collaborate with students, to get along well with students, to help the student, to have good relations with students”;

IV. 6.86% evoke the role of a technician, who must use effective learning methods, which establishes various learning situations, use different didactic materials and technical means. The students state: “to teach to be understood, to train them in such a way that they become able to integrate in life; to transform the student into a subject of learning; to focus on quality first; to fit the students in the activity as efficiently as possible; to direct in a good, logical order; to teach the assignment using the computer or other tools; to teach well and for everyone to understand”;

V. 6.86% appreciate the role of the teacher as an evaluator of student performance and leader of the instructive-educational process in chemistry, and 2.94% consider the professional roles of being a manager and researcher important.

As a result, most students, 67.64 %, identified the teacher’s primary role as guiding, instructing, and shaping the students’ personalities. Most students (76.47%) emphasized 4-5 roles of the modern chemistry teacher. A teacher's role involves activities in which he represents the public authority, is a knowledge transmitter and educator, is an evaluator of the students' activity, and is a partner of the parents in carrying out educational activities. Teaching staff must act as a foundation for stimulating subject learning throughout their lives, which is especially important for personal development, social inclusion, active citizenship, and employment.

The students' answers to **item 6,** ***"Explain the role of pedagogical practice in initial professional training",*** emphasize the importance of pedagogical practice as the best opportunity to raise awareness and capitalize on the usefulness and relevance of educational psychology, pedagogy, and specialty didactic courses. That is why practical methodologists and mentors work to ensure a unified approach, causing cognitive confusion in chemistry students.

The role of the teacher-methodologist in their practical training is regulation, counseling, methodological guidance, information, organization, evaluation having a great weight. Teaching practice contributes to the improvement of the quality of the educational process, the organization and effective implementation of the practical training internship; contributes to supporting and encouraging the individual development of students and their training as a specialist to know and achieve performance standards.

Analyzing the responses of chemistry students regarding the role of teaching practice in professional training, we determined that during pedagogical practice they can become capable:

I. to know the specific way of organization and operation of the educational units;

II. identifies the main responsibilities, obligations and rights that the quality of teacher imposes and integrates them into the work activity and discipline specific to the school institution;

III. to acquire the methods of knowing the students' individuality;

IV. utilizes pedagogical knowledge practically and in varied conditions;

V. to design, realize and evaluate a didactic sequence, a lesson;

VI. to know the psychological profile of children.

To **Item 7**, ***"For the formation of initial professional competence, it is necessary..."***, chemistry students responded by emphasizing the importance of self-instruction and professional self-training. "Pedagogical practice requires effort, determination, daily work, responsibility, conscious learning, systematic learning, good attendance at classes, and other statements", students responded. If we examine the answers in the key to the curricular requirements of professional training based on the concept of the Basic Curriculum regarding the initial training of teachers in the field of chemistry, which states that university teachers involved in teacher professional training must capitalize on focusing on individual training, focusing on active learning, active integration of research-learning-application, connection to national educational standards.

Updating the principle of focusing on individual training, 84.31% of the subjects mentioned the following statements "to make great efforts and to persevere continuously"; "the theoretical activity of information, practice, carried out in a real professional context, to show character, desire and effort, information and research; cognitive, affective, motivational capacities; of advanced knowledge in the field of professional training; to work and give as much time as possible for a good success; to observe the way of work – teaching several teachers, then training one's own capacities; to like what you do, to strive to make others like what you do, and to take maximum responsibility; to develop creativity, activism, to study continuously; a lot of perseverance, work, knowledge and abilities".

In order to promote the concept of Centering on Active Learning, the students' responses emphasized the need for professional staff who can create those learning situations and actively involve students. 25.49% of respondents state that competent teachers, modern teaching-learning-evaluation methodologies, provision of didactic materials and technical means, perseverance, desire, ambition, knowledge, general information, continuous work, professional development, character, desire and effort, information and research, constantly developing capacities.

In terms of students' interest in capitalizing on the concept of active integration through research-learning-application, we can see from the answers (45.1%) that they recognize its impact on professional "if they studied more, it would be more competences, to practically apply what we learn, to learn by ourselves, to practice more; theoretical activity, and practical information, carried out in a real professional context; knowledge and application in practice; discovering new things every day; a lot of patience, knowledge and a lot of dedication; to know at an average level the information related to the field you have chosen in your personal career; studying, researching, accumulating information necessary for the desired field, bringing to the knowledge of the theories, implementing the theoretical and practical ideas of the lessons, to make great efforts and persevere continuously, etc."

According to the system of ideas promoted by the concept of Connecting to national professional standards, 17.65% of the subjects emphasize the importance of connecting pedagogical efforts to achieve the competence standards formulated in terms of goals.

Some sequences from the students' answers demonstrate the insufficient awareness of this desired professional training: to give more and more time to be successful, to observe the teaching strategies of several teachers, then the self-training methodologies; to train your capacities for organization, analysis, communication, understanding of the didactic message, application of knowledge, skills and attitudes; studying, researching, accumulating information necessary for the desired field, introducing theories, implementing the theoretical and practical ideas of the lessons; it is necessary to have knowledge, skills; of lasting knowledge; skills to explain the new topic well; effective communication abilities, to know as many teaching-learning-evaluation methods as possible; to be more daring, to learn from others how to work with the audience; the ideal teacher must approach the study of the subject he teaches not as an end in itself, but as a means of achieving educational objectives; to make maximum efforts to acquire these essential skills and to persevere continuously; the student to attend classes and be motivated by the teacher to do so, appropriate dress, free exposure, communication skills etc.

Some of the student answers to the item are displayed in Figure 3.11.

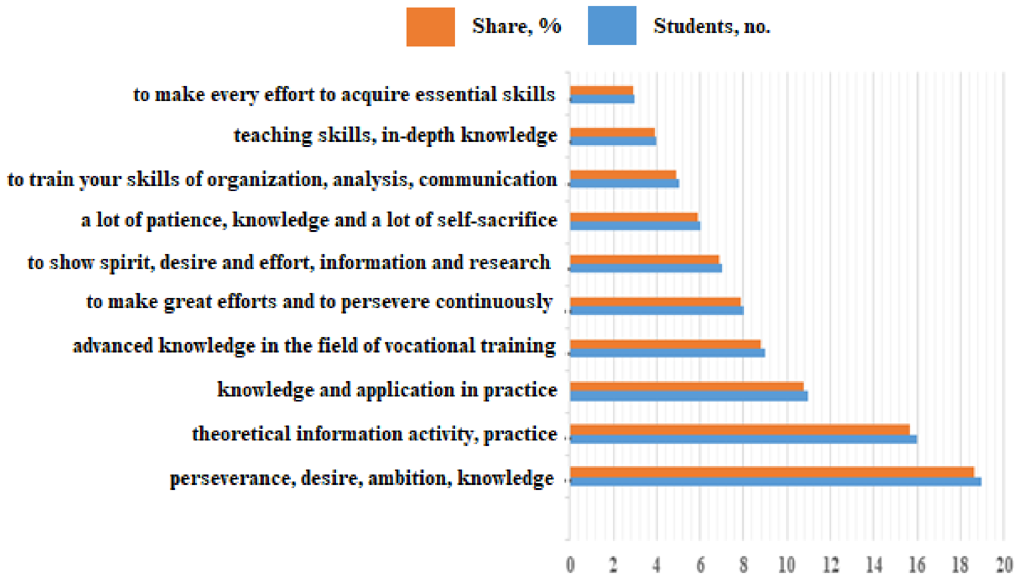


Figure 3.11. Directions for strategic action in the training of professional competences of chemistry students

The analysis of the students' responses demonstrates the need for improvement and change at the level of institutional policies: personnel policy, relationship policy, resource policy, curriculum policy, and so on, through concrete actions to improve the efficiency of professional actions. In this sense, we conclude that students in their first and second years of study are still unaware of the need for active participation in their own training, which the teacher creates by emphasizing the impediments that create barriers to their active participation in the act of learning. The low level of their professional training model is indicated by the small number of students who are aware of the role of active learning, the need to integrate it in individual research, and the need for knowledge.

The majority emphasizes their low potential for success, reasons that they require conditions, human models, and capacities, denotes the fact that they find excuses for personal lapses, and is aware of their role in initial professional training. Students are aware of the importance of acquiring knowledge and practice, emphasizing the learning process and their own effort (84.31%), noting that their active participation in the lessons would contribute to the development of the necessary professional competences.

If we compare these data with the identified features, we conclude that in the respondents' view the qualities resulting from the awareness of the need for professional affirmation of the students (the personal EGO) predominate and not depending on the demands of society and the teacher's activities. The argument is the placement of the inevitable qualities of the conscious, tactful, patient, honest, model teacher on the last places in the top of the ten identified, valued in the foreground being the qualities: understanding, objective, kind, friendly.

Students highlighted the priority qualities that, in their opinion, define the professional profile of modern chemistry teachers in **item 8,** ***"The current roles of the modern chemistry teacher",*** as shown in Figure 3.12.

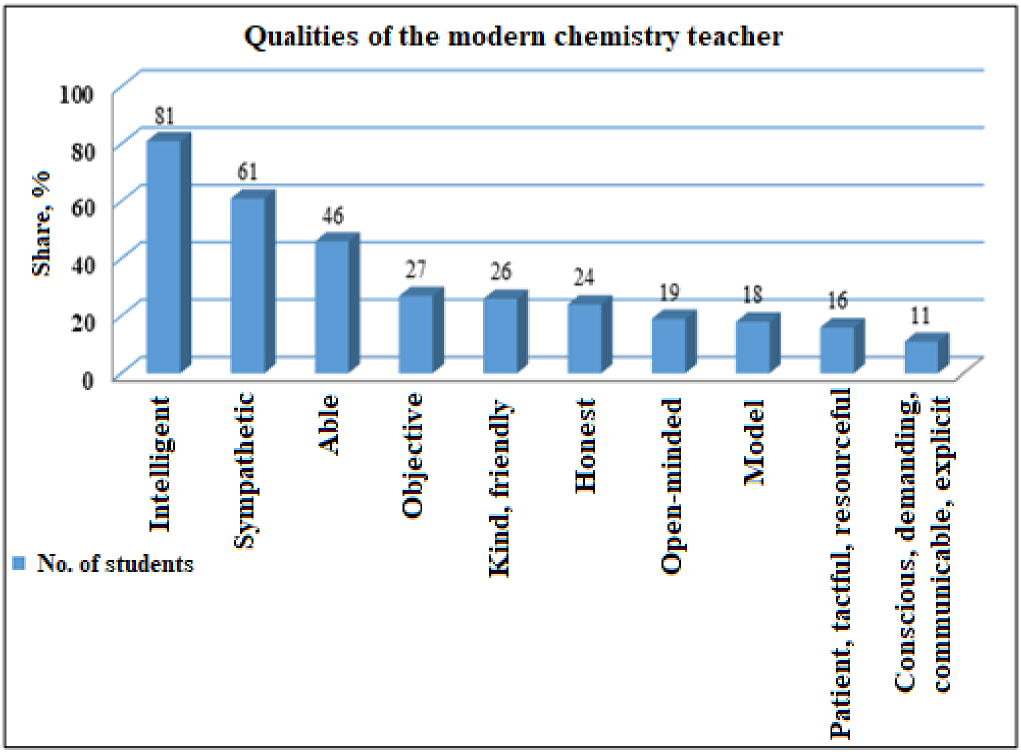


Figure 3.12. The register of qualities of the modern chemistry teacher

Being a modern chemistry teacher necessitates a set of physical, intellectual, affective, and moral characteristics. Thus, the teacher's personality structures were identified, on which the efficiency of the students' learning is dependent. The students identified the following personality traits: flexibility, democratic attitude, rigorous ordering and planning of activities, human warmth (kindness), sense of humor, openness to people's problems, understanding problems of those with whom they work, collaborative style, intelligence, strong emotional stability, weighted approach to problems, balanced, lucid character, authority, prudence, delicacy, ability, sincerity, seriousness, sense of duty, bravery, sociability.

It is encouraging that most emphasize intelligence and competence, but it is unfortunate that the following qualities are not regarded as important: authority, prudence, sincerity, seriousness, sense of duty, sense of humor, bravery, sociability, creativity, punctuality, openness to people's problems, and strong emotional stability. **Item 9** ***"Which components of professional competence do you want to develop within the faculty?"*** was used to determine the individual priorities (professional competences) of chemical students. Competences, as educational purposes, oriented as a necessity to current practice demands and valid for the entire educational process, also express the social dimension of education, allowing graduates to assert themselves through functional competences to successfully solve professional problems.

Based on the taxonomy of professional competence, the students named the following types of elements of professional competence (Figure 3.13).

Table 3.4. Elements of professional competence obtained within the faculty

| Components | Students, no. | Share, % |
|---|---|---|
| gnoseological component | 11 | 10.78 |
| praxiological / instrumental component | 17 | 16.67 |
| managerial component | 4 | 3.92 |
| evaluation component | 3 | 2.94 |
| prognostic component | 2 | 1.96 |
| communicative and social integration component | 40 | 39.21 |
| scientific research component | 12 | 11.76 |

The development of competences will be oriented toward achieving the complex training of students, allowing them to progress to the next stage/level of education and/or social integration. It is encouraging that the pedagogical students identified the following competences: communicative and social integration, praxiological/instrumental, and scientific research. Fewer students identified the following competences: managerial (3.92% of students), evaluation competence (2.94% of students), and prognostic competence (1.96% of students).

**Item 10** was the most difficult for chemistry students. ***"What do you propose for the effective training of the initial professional competence of a chemist within the specialty?"***. The survey results are reflected in Figure 3.13.

Some specific elements can be identified that refer to the initial training of general education teachers in a modern perspective, based on social, psychological, and pedagogical foundations, and adapted to the requirements and contemporary trends of European education systems.

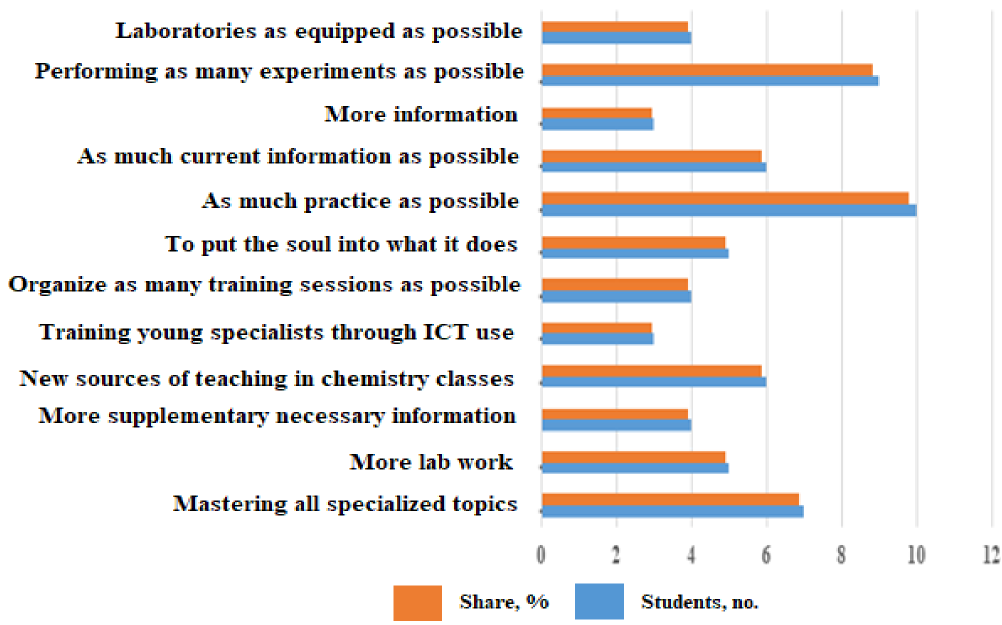


Figure 3.13. The share of actions proposed for the formation of the initial professional competences of chemistry students

The analysis of the questionnaire directed us towards the determination of a series of factors that create difficulties in the process of initial professional training: the inability to formulate the definition of professional competence, competence conceived segmentally, the equating of competence: with knowledge, abilities, personality traits, insufficient knowledge of the taxonomy of professional competences, the inconsistency of professional finalities with the professional field, the diminishing of the importance of personal qualities, the insufficient perception of professional roles: a) instructor, guide; b) technician; c) organizer; d) by the evaluator; e) by researcher; f) group leader; confusion of the teacher's roles, subjective view of the significant characteristics of the teacher, etc.

These pre-experiment results were used in the subsequent phases of the experiment (finding, training, and control), with the results presented below.

## 3.2. INITIAL LEVELS OF PROFESSIONAL TRAINING OF THE SPECIFIC COMPETENCES OF THE STUDENTS FROM THE FACULTY OF BIOLOGY AND CHEMISTRY

The experiment's objective at the finding stage was to determine the initial level of training of specific competences of chemistry students prior to implementation of the interdisciplinary curriculum *Chemistry for Life – Integrated Research*, as well as the level of integration of scientific knowledge obtained separately in study programs by students. Prior to the implementation of the optional interdisciplinary curriculum, 64 first and second year students from the specialties of Chemistry, Chemistry and Biology, Biology and Chemistry (day section) participated in an oral (guided) questionnaire. After describing the structure and content units of the free choice interdisciplinary course / discipline, they were asked to answer the following questions:

The question of the questionnaire on "the need of students to listen to an interdisciplinary course, at the free choice *Chemistry for Life – Integrated Research*" included in the study program that would contribute to the formation of specific competences in the field of chemistry? Most students (70.31%) stated that they accept the requirement to study the optional integrated course because some elements of the course are studied in the faculty in different semesters, resulting in a loss of the connection between knowledge and capacities. This course, based on the proposed modules: Synthesis - Determination of composition and structure - Chemical modeling - fields of application (ecological aspect), will contribute to the formation of specific competences required by chemists through an interdisciplinary approach to content [2-9].

The second question of the questionnaire concerned specific competences that could be developed through the interdisciplinary course *Chemistry for Life – Integrated Research*: a) investigative, b) communicative, c) digital, d) ecological, and e) continuous training (Table 3.5 and Figure 3.14).

Table 3.5. Specific competences designed for the discipline *Chemistry for Life – Integrated Research*

| **Course specific competences** | **Students, no.** | **Share, %** |
|---|---|---|
| investigation competence | 48 | 75.0 |
| communicative competence | 56 | 87.5 |
| digital competence | 60 | 93.75 |
| ecological competence | 58 | 90.62 |
| continuous training competence | 39 | 60.94 |

The experimental group included 31 first and second year students from the specialties of Chemistry, Chemistry and Biology, Biology and Chemistry, and Biology and Chemistry (full-time). The finding stage of the pedagogical experiment was organized in common conditions, during the 12-week internships, with specific teaching activities in the usual university learning environment, and involved the analysis of the evolution of subjects at all stages of the pedagogical experiment organized and conducted within the Tiraspol State University, Chisinau, the Republic of Moldova.

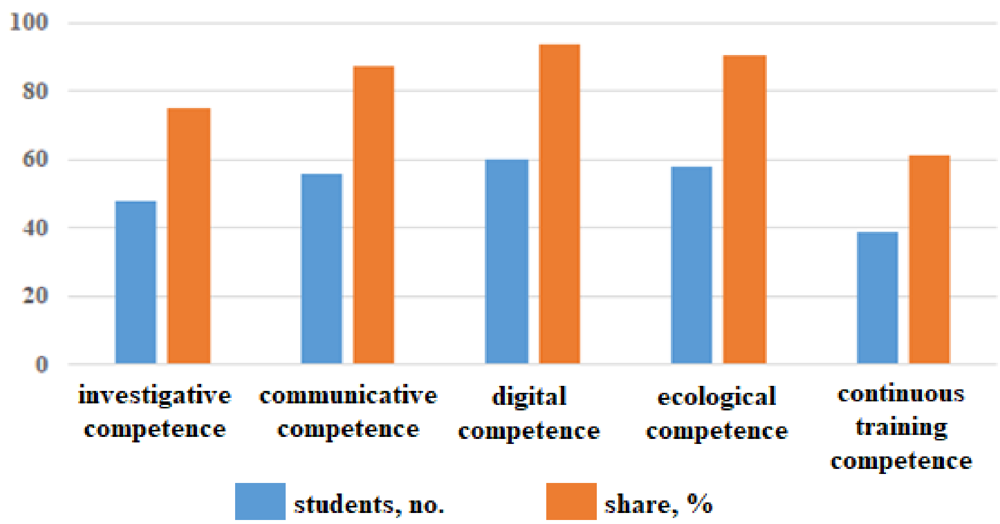


Figure 3.14. Specific competences designed for the discipline *Chemistry for Life – Integrated Research*

The ascertainment stage occurred in September 2019, prior to the start of the course *Chemistry for Life – Integrated Research*. Table 3.6 shows the evaluation criteria and descriptors.

Table 3.6. The reference framework for assessing the initial level of specific competence of chemistry students

| Competences | Evaluation criteria | Evaluation descriptors |
|---|---|---|
| *Investigative competence*<br>*Professional communication competence*<br>*Digital competence*<br>*Ecological competence*<br>*Continuing vocational training competence* | • *motivational component* (the value of career guidance, reasons and interests, aimed at training and chemistry, the need for creativity of future chemists, and ways to improve their professional experience);<br>• *cognitive component* (the quality of theoretical and practical knowledge formed and developed during the study of chemistry, biology, physics, computer science and the individual);<br>• *action component* (understanding of actions, ability to make decisions, professional creativity, professional communication competence and self-esteem); | 1. Depth of answer<br>2. Logic<br>3. Consistency<br>4. Coherence of actions<br>5. Relevance of the answer<br>6. Originality of ideas |

| | | |
|---|---|---|
| | • *reflexive component* (the ability to consciously solve the problem, to evaluate the results of their own learning process and to reproduce the experience gained because of initial professional training). | |

The experimental research methods refer to: questioning, structured individual conversations.

The reference levels covered:

Level I (high);

Level II (average);

Level III (low);

The quality of the answers was assessed according to the following grades: high, average, and low. Degree of evaluation in percentages: the answer is correct, logical, consistent, relevant, and original – 100%; the answer is at the average level, with some inaccuracies, less logical and consistent, less relevant, and original – 50%; the answer is at the low level as for accuracy, logic, consistency, relevance, and originality – 25%. Analyzing the responses provided by the people involved in experiment, the distribution was made by levels according to the indicators, using the evaluation degrees (in %), and the quality of the results was rearranged as level 1 (high); level 2 (average); and level 3 (low).

If we differentiate on the reference levels, then the first-year students, compared to the second-year students demonstrated level II (50%) and level III (25%). In most cases, students' answers are inconsistent, irrelevant, and unoriginal.

Below there are the students' responses in the initial assessment, the finding stage (Table 3.7): some respondents, for example, confuse the concept of coordinating compound (**item 1**) with that of chemical substance, providing answers such as – $CuSO_4$, $PbCl_2$, NaCl, HCl, $H_2O$, $N_2$, $H_2$, $O_2$, Fe, Ag, and so on. Students who correctly answered referred to chlorophyll, hemoglobin – notions (substances) that they know from the biology course taken in school.

In **item 2**, five first-year students named elements (metals) with physiological action, explaining their critical importance, such as calcium (Ca) – in the formation and support of the vertebrate bone system; magnesium (Mg) – for normal heart function; iron (Fe) – is part of the blood, its lack leading to anemia; potassium (K) and sodium (Na) – for normal muscle function. Most respondents mentioned only a few elements without further explanation.

At **item 3**, most students responded superficially, with some still attempting to bring examples of simple chemical compounds and explain the correlation: *composition → structure → properties → practical importance*.

In the case of **item 4**, the instrumental methods for determining the composition and structure of chemical compounds, nearly half (51.43%) of the total number of students (35) do not know or are confused, and they are classified as follows: methods, physical methods, chemical methods physico-chemical.

Table 3.7. Levels of training of students' professional competences

| **Professional competence** | **Questionnaire items** | **Year of study** | **Students, no.** | | | **Degree of evaluation, %** |
|---|---|---|---|---|---|---|
| | | | **Level** | | | |
| | | | **I high** | **II average** | **III low** | |
| investigative | 1. What examples of coordinating compounds in nature do you know? | I | 4 | | | 100 |
| | | | | 1 | | 50 |
| | | | | | 20 | 25 |
| | | II | 5 | | | 100 |
| | | | | - | | - |
| | | | | | 5 | 25 |
| investigative; communicative | 2. Do you know any elements (metals) of vital importance or stimulation of physiological processes? | I | 5 | | | 100 |
| | | | | 18 | | 50 |
| | | | | | 2 | 25 |
| | | II | - | | | - |
| | | | | 9 | | 50 |
| | | | | | 1 | 25 |
| investigative; communicative | 3. Explain the relationship: *composition → structure → properties →* | I | 2 | | | 100 |
| | | | | 13 | | 50 |
| | | | | | 10 | 25 |
| | | II | - | | | - |
| | | | | 8 | | 50 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | *practical importance.* | | | | 2 | 25 |
| investigative | 4. Do you know of any instrumental methods for determining the composition and structure of chemical compounds? | I | 2 | | | 100 |
| | | | | 10 | | 50 |
| | | | | | 13 | 25 |
| | | II | - | | | - |
| | | | | 5 | | 50 |
| | | | | | 5 | 25 |
| investigative; ecological | 5. What is the importance of using contemporary instrumental methods to determine the quality of pharmaceutical, food and industrial products? | I | - | | | - |
| | | | | 13 | | 50 |
| | | | | | 12 | 25 |
| | | II | - | | | - |
| | | | | 5 | | 50 |
| | | | | | 5 | 25 |
| digital | 6. Do you know and use any software specific to the field of Chemistry? | I | 2 | | | 100 |
| | | | | 2 | | 50 |
| | | | | | 21 | 25 |
| | | II | - | | | - |
| | | | | 6 | | 50 |
| | | | | | 4 | 25 |
| digital; communicative | 7. What methods of modeling the composition and structure of chemical compounds do you know? | I | - | | | - |
| | | | | 5 | | 50 |
| | | | | | 20 | 25 |
| | | II | - | | | - |
| | | | | - | | - |
| | | | | | 10 | 25 |
| digital; ecological; communicative | 8. Do you know any digital applications that can be used to determine the quality of environmental factors? | I | 1 | | | 100 |
| | | | | 4 | | 50 |
| | | | | | 20 | 25 |
| | | II | - | | | - |
| | | | | 5 | | 50 |
| | | | | | 5 | 25 |

So, 42.86% of students mention methods as chromatography, photocolorimetry, and spectrometry, but only 5.71% attempt to explain their application. At **item 5**, the responses were split evenly between NI (18 people, 51.43%) and NIII (17 people, 48.57%), with those from NIII either not knowing or providing less accurate, logical answers. And those from NII - that they are efficient, fast, and accurate, allowing them to determine the quality of food, pharmaceutical, or industrial products in a short period of time. These are essentially those who responded to item 4 by saying they are familiar with some analytical methods.

In general education, the ineffective use of software specific to the field of Chemistry was found in the responses to item 6, in which 71.43 percent of students stated that they do not know or have become confused with some applications, elementary programs that they know from the course computer science in school such as: Word, Excel, PowerPoint, with only 22.86 percent of respondents naming specific applications for Chemistry: ChemDraw, ChemBioDraw, ChemLab, ChemixSchool, Molec. Mass. Calc. and only 5.71 percent of subjects used these applications: writing molecular formulas and chemical compound structure, calculating chemical compound molecular weight, and the virtual chemistry laboratory. At **item 7**, 85.71 % of respondents did not know how to model the composition and structure of chemical compounds, and 14.29 % of those who did know referred to bile-axis modeling. In **item 8**, most respondents (71.43 percent) admitted that they are unaware of digital applications that can be used to determine the quality of environmental factors, and those who are aware (28.57 percent) referred to sensors, digital barometers, and detectors of nitrate levels in fruits and vegetables.

## 3.3. DIDACTIC TECHNOLOGY FOR PROFESSIONAL TRAINING OF THE RESEARCH COMPETENCE OF CHEMISTRY STUDENTS

At the present time, the methodological option for university didactic technology for professional training of chemistry students' research competence is guided by the following principles: connecting the pedagogical actions to the professional, cultural and spiritual universe of the students; capitalizing on the individual potential of the student; achieving educational objectives; coherence and epistemic validation of contents; timely involvement of the psychological sphere; continuity of applied technologies with learned technologies, etc.; focusing on the paradigm of the profession and anticipating the perspectives of vocational training. Higher education, and particularly university teaching technology, must be renewed as a matter of professional concern and obligation for university teachers.

One of the priority dimensions of educational policies is the tendency to orient higher education toward the formation of professional competences by capitalizing on research training: competences-centered curriculum, competences standards, competences assessment, and so on. From this point of view, special attention is drawn to interactive teaching strategies, among which heuristic training has roused the interest of researchers in recent decades, due to its connection with problematic training. The degree of complexity distinguishes heuristic training and problematic training, which are both widely studied in the university setting. In this sense, we specify that learning through problem solving is a method of applying learning through discovery because of capitalizing on problematization-based teaching strategies.

The complexity of the purpose, oriented towards the vector of professional development of students by tracing the objectives, contents, and strategies of self-directed learning, validates the heuristic model of university learning. Students participate in learning situations in which they manage their own training. In this context, the university teacher evolves from an information source and transmitter to a guide, facilitator, and designer of the design and accumulation of new learning experiences through research. Establishing a balance between university teachers' authority and students' autonomy involves accepting responsibility for tracking learning progress. The first question is the following: *what heuristic strategies can be used to train research competences*?


Figure 3.15. The heuristic approach in the professional training of research competences

In recent decades, the methodologies for developing study programs have taken on an innovative character, with university education focusing on fields that support the development of investigative and reflective competences, as well as the ability to analyze critical situations through research actions. In this context, students' real difficulties refer to states of discomfort, cognitive tensions, manifestations of confused states, disorganization tendencies, and intrapersonal conflict and dissatisfaction. Against this background of research and reflection, the students' interest is to discover university teachers' interests in order to guide research intentions.

University teaching technologies used to guide students' research projects aim to conceptualize the set of methods, teaching aids, and strategies for organizing teaching-learning that are implemented in the interaction between teachers and students, through close cooperation from the viewpoint of ensuring an optimal degree of achievement of pedagogical objectives, through transmitted university contents, forms of reorganization of training, and evaluation methods. Thus, the university didactic strategies, through which we understand a complex and circular set of methods, teaching means, and forms of activity organization, on which the professor develops a pedagogical action plan to ensure the transformation of theoretical landmarks and methodological provisions into activities. practical in accordance with the intended goals, the logic of the process stages, the interconnection and unity of the structural components. However, in all cases, the dimensions of technology described below will refer to the epistemological dimension (a theoretical construct that is internal congruent and coextensive with certain scientific norms) and the pragmatic dimension (operational and methodological).

As a result, the heuristic strategy for the development of research competence in higher education presupposes a model of creative psycho-pedagogical action of university teachers, which aims at the tendency to actively approach and adapt university teaching technologies, to capitalize on direct knowledge experiences for integration in the university didactic activity of new teaching-learning-assessment strategies through discovery, which ensures to the students the adequate use, development and creation of the new scientific knowledge necessary for the professional training of the students.

The didactic technology for training chemistry students' professional competences in an interdisciplinary context aims to guide learning through independent study for the complex use of investigative potential, has a discovery character, and serves as a theoretical-methodological basis for developing the Interdisciplinary Curriculum *Chemistry for Life – Integrated Research*. During September-December 2019, the Interdisciplinary Curriculum *Chemistry for Life – Integrated Research* was implemented using a variety of interactive strategies based on learning situations in which students assimilate the interdisciplinary content and form their competences system. The didactic strategy represents a method of efficient and optimal combination of learning methods and means in the process of teaching-learning-evaluation of chemistry. In the training experiment, the following strategies were used (Table 3.8):

I. *metacognitive* (awareness of one's own cognitive processes);
II. *research* (the ability to find information by navigating within a network);
III. *heuristics* (solving problems by acquiring new knowledge);
IV. *of interaction* (negotiating meanings by interacting with the teacher and colleagues);
V. *of interactivity* (electronic simulation of the interaction process).

The teaching-learning-assessment process is a method for university teachers and students to actively participate in problem-solving learning activities. Learning strategies, in this way, lead to the development of scientific knowledge, capacities in an integrated and integrative manner. University didactic strategies, in their capacity as models of didactic action, employed on concrete pedagogical paths more extensive than methods, constitute a major direction for improving university education process methodology.

Table 3.8. Interactive heuristic strategies for training professional research competence

| **Training stages and competence units formed at students** | **Interactive heuristic strategies** |
|---|---|
| **know** | Explanatory-investigative strategies through semi-guided discovery, seminars, laboratory works, comparisons, multimedia applications |
| **know how** | Investigative-explanatory strategies by initiating experiments, debates, portfolios, hypotheses, essays, thematic maps |
| **know how to be** | Experimental exploration strategies through project development, modeling, case studies,<br>Strategies based on heuristic conversation,<br>Strategies based on team research, etc. |

The scientific knowledge that students absorb serves as the foundation for the development of their personalities. The presence of new scientific information contains formative valences, and the mere existence of scientific information accumulated by students does not guarantee the positive dynamics of professional training. It relied on continuous and productive intellectual activity to generate professional knowledge and convictions, personal abilities and attitudes, and self-motivate students for autonomous learning of the profession in order to form professional competences in the field of chemistry. The training experiment was founded on *the constructivist paradigm*'s main methodological norms and principles. In this context, the capitalization of constructivist theoretical precepts begins with the thesis that reality, while objective, does not reveal itself unless the knowing subject (students) processes the information they accumulate through progressive mental constructions. However, information is accumulated not only through direct experience, but also through synthesized data, consolidated cognitive experiences, and can serve as starting points for professional self-training through research. Based on E. Joiţă's proposed essence of processing, four stages were followed: primary information processing, which includes early processing (sensations) and deep processing (perceptions); formation of mental images; abstract information processing through processing mechanisms such as operations, procedures at the level of thinking; and the final stage – processing knowledge in memory (encoding, storage, retrieval) [10].

In the context of a constructivist approach, we will argue that the following criteria must be met:

1. The learning process is one of mental construction, that is, it is a process based on which a legal representation of the world is established.
2. Interpretation is personal, which means that each student constructs his or her own interpretation of reality. It is critical that such interpretations always depart from reality.
3. Learning is active, which involves the student's implication in the search, processing, understanding and development of knowledge and relationships.
4. Learning necessitates collaboration, which means it is dependent on interpersonal relationships and communication with peers.
5. Learning is contextual (the process of learning takes place in situations that are important to students and relevant professional contexts in which additional information will be used [11, p. 18].

Obviously, the constructivist-based university training process cannot consist solely of memorizing and reproducing theoretical information; rather, it resides, in particular, in placing students in different situations, allowing them to build knowledge, appreciation, and elaboration of systems and models of action, ie emphasizes the learner. Teaching is important, but as we've seen, learning is at the heart of specialized training. Individual knowledge (subjectivism) is founded on direct exploration, previously updated cognitive experience, and intellectual work tools. In this context, constructivist learning entails comprehension, exploration, and self-interpretation. During this exploration, the student will perform psychological operations such as processing, organization, structuring, schematization, and balancing. As a result, he will only become a specialist through construction. For these reasons, the student's affective and internalized action involves confrontation and collaboration with the other; it places students in a unique situation of learning, education, and problem solving, allowing students to develop cognitively, axiologically, and praxiologically. Being active implies that you are acting. In this order of ideas, it is possible to state that the learning activity is oriented toward the one who realizes it; thus, towards the one who is formed. The design stages of teaching-learning-assessment activities in chemistry students were determined by analyzing constructivism principles, guidelines for efficient learning, and the structure of professional competences according to the Standards. The stages of designing educational activities for chemistry students include the following: objective, methods and means of action, interest and motivation, action implementation, results / products of action, reflection: self-analysis of actions, and student progress. Objective – any educational activity has a specific purpose that is materialized by one or more objectives depending on the type of lesson. Methods and means of action are ways to achieve and tools of activity used in the educational process to achieve the intended educational objectives.

Interest and motivation – stimulation for learning is an important component of any educational process; lack of interest in learning has implications for the finalities and effectiveness of learning.

Carrying out the actions – the student carries out the actions that have been organized according to the exposed logic in order to achieve the predetermined objectives.

Action results / products – at the end of each activity, the student is to obtain specific results or products. Figure 3.16 depicts A table with the structures and geometric parameters of the studied molecules, a solved problem, and so on.

Reflection: action self-analysis – the finality of any educational activity is to analyze the effectiveness of actions taken, identify gaps and ambiguities, and improve the quality of actions taken.

Student progress – the outcome of any training process must result in positive growth, development, or change; achieving success represents the student's progress in a particular field.

The stages of designing educational activities are distinct for each stage of training the professional competence to know, to know how to do, to know how to be, and to know how to become.

The finalities of constructivist didactics are diverse: training abilities, competences, training for research, training abilities of independent and social activity, problem solving, overcoming obstacles, decision making, cognitive mechanisms. In this context, we consider the role of constructivism in the development of a chemist student's professional competence.

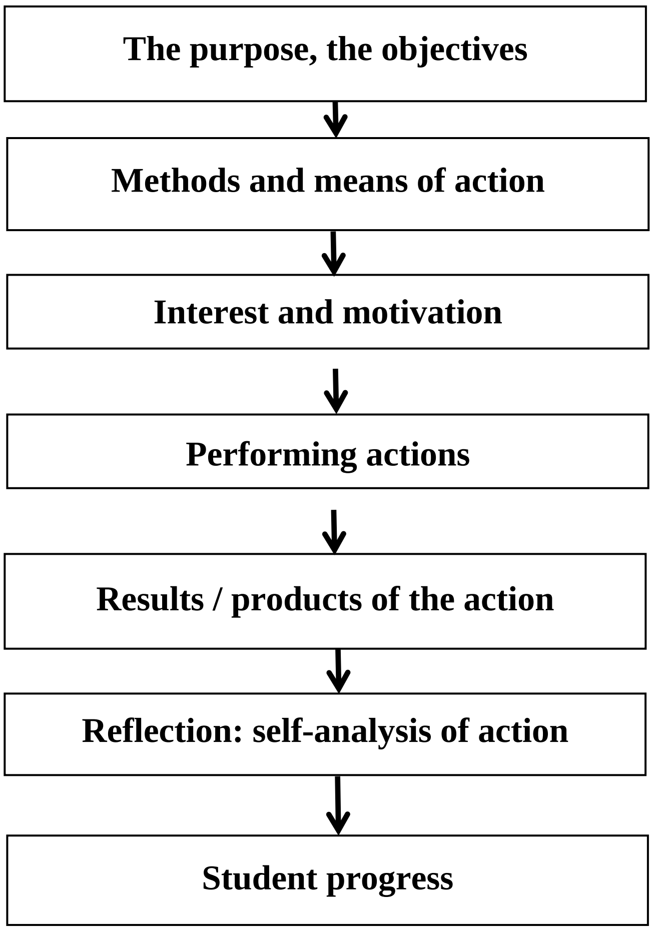


Figure 3.16. Stages of designing teaching activities for chemistry students

The learner will be the focus of the interdisciplinary curriculum: *Chemistry for Life – Integrated Research*, in accordance with the stated objectives. The student is central to constructivist training: he/she observes, critically analyzes, mentally constructs, interprets, and formulates hypotheses, solves variously, designs, proposes, develops, cooperates, negotiates, and appreciates. He/she evolves into a collaborator, an explorer of scientific knowledge in the own unique style, but with reference to the group. To achieve this, he/she will begin with a natural curiosity and an internal motivation to learn. He/she will use self-knowledge, critical self-analysis, direct and immediate self-motivation in the process of knowledge (metacognition); he/she will be aware of the level, evolution, obstacles, and failures; and he/she will use in cognition different authentic, manipulative, interactive, stimulating materials, with the teacher motivating them. The teacher's role is to ask open-ended questions, giving the student enough time to seek answers on their own. The teacher observes, interactively guides, supports, trains, and collaborates. He/she is a democratic manager who will make certain that learning tasks are related to situations, real, authentic cases that are presented directly or simulated. The constructivist strategies and methods used in university education primarily aim at: projects, case studies, experimentation, cooperation, essays, debates, thematic maps, multimedia applications, hypothesis formulation, comparisons, arguments, and communication.

### 3.4. VALUES OF THE PROFESSIONAL RESEARCH COMPETENCE OF CHEMISTRY STUDENTS AFFIRMED IN AN INTERDISCIPLINARY CONTEXT

In terms of university education, the priorities of the third millennium are the development of professional competences in general and research competences, in particular, with the goal of integrating research activities into the university didactic process. Personality intellectual capacities are directly related to the quality and quantity of knowledge and action experiences, as well as the ability to mentally integrate these knowledge and abilities in order to integrate in both the natural and social environments. The active process of training and developing research competence will result in the creation of the necessary context for a quality education and will initiate the students in the techniques and methods of intellectual work, develop the interest in knowledge, motivate to study the discipline of chemistry, which will ultimately lead to the formation of their own conception and vision about the surrounding world and life [12].

According to the field of knowledge, chemistry is an experimental science. Thus, the primary activity of Chemistry students is training through experimental research. Students' participation in research activities develops the units of specific investigation competence, which is an important stage in the formation of an innovative personality capable of fully analyzing natural phenomena. A scientific investigation necessitates the use of a diverse set of investigation methods to determine the composition, structure, and properties of new chemical compounds, as well as the fields of application [13].

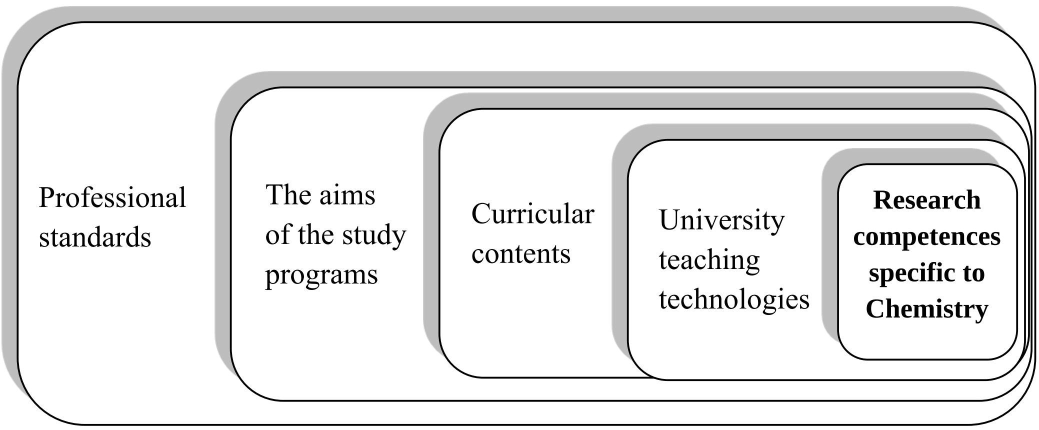


Figure 3.17. Evolutions from professional standards towards the complex engagement of research competence in the professional training of students

We deliberately derive the wide valorization of the experiment as a research method that favors the realization of a close connection between theory and practice, the solution of some scientific-technological problems, and the acquisition of new knowledge from the aspirations of postmodern didactics. The experiment, designed on constructivist didactic principles, takes the student through all the hierarchical steps of learning, from observation of some phenomena, processes from nature through their own activity, to systematization and generalization in certain laws, principles specific to chemistry. As one of the most active methods with applied value, the experiment is combined as a method with the case study. Observation within an experiment is an important source of direct information, but it is also a method of knowledge, analytical and systemic thinking, research competences, independent causal thinking abilities, and arousing interest in any activity. In order to carry out the experiment, the students must act consciously not only on a separate object, but also think complexly about the expected causes and effects, consciously combining previously acquired knowledge and abilities with those formed during the experiment. In the context of scientific research, intuition is developed, allowing for investigations with predictable outcomes and creating conditions for the development of capacities such as deduction, comparison, systematization, analysis, and so on. As a result, constructivist instruction is based on knowledge-grounding techniques that provide new constructivist developments, so that if we advocate effective learning in the context of professional competence formation, students must construct their own knowledge, elaborating answers to questions they and he set for themselves, carrying out experiments, and adapting their behavior to unpredictable situations of professional life.

The development of initial professional competences in the field of chemistry involves a continuous and productive intellectual activity that produces professional capacities and attitudes in students. Chemistry is an experimental science, according to the field of knowledge. Chemistry students' primary activity is training through experimental research. The use of modern information and communication technologies in the training process creates new opportunities for the training and development of field-specific professional competences, as well as the achievement of individual motivating tasks. Following the formation of the fundamental elements of professional competences, the discipline-specific professional training process based on:

***A. Knowledge***, as a cognitive dimension and structural element of competence, is expressed through the following descriptors:

- cognition (the process of knowing), understanding and use of the specific language;
- explanation and interpretation.

***B. Capacities***, as a functional-action dimension and structural element of competence, are expressed through the following descriptors:

- application, transfer and problem solving;
- critical and constructive reflection;
- creativity and innovation [14].

***C. Attitudes,*** as an evaluative-affective dimension, formed through experience, being influenced by external factors and expressed through the following descriptors:

- action, involves a person-object relationship;
- polar character, correlated with values;
- regulatory, adapting and value-expressive function [15].

***D. Transversal competences*** represent value and attitudinal acquisitions that transcend a certain field/study program and are expressed through the following descriptors:

- autonomy and responsibility;
- social interaction;
- personal and professional development [14].

Schematically, the relationship between the competence descriptors, the actual training process, and the output-qualification is presented as follows (Table 3.9):

Table 3.9. The relationship between the competence descriptors, the training and qualification process

| **Descriptors** | **Process** | **Output-qualification** |
|---|---|---|
| 1 | 2 | 3 |
| *"to know how to become"* | Practical simulation activity Training | *constructive professional behaviors* |
| | Social interaction | |
| individual values (cognitive, affective, behavioral dimension) *"to know how to be"* | Autonomy and responsibility | *constructive behaviors* |
| | Creativity and innovation | |
| Abilities (functional-acquisition dimension) *"to know how to do"* | Critical reflection and problem solving | *functional knowledge* |
| | Application, transfer and problem solving | |
| knowledge (cognitive dimension) *"to know"* | Explanation and interpretation | *procedural knowledge* |
| | Knowledge, understanding and use of the specific language | *declarative knowledge* |

So, the training of professional competences within the optional integrated interdisciplinary discipline went through four successive stages:

- the stage of fundamental knowledge "to know",
- the stage of functional knowledge "to know how to do",
- the stage of internalized knowledge "knowing how to be",
- the stage of externalized knowledge "to know how to become".

**1. The stage of fundamental** *(declarative)* **knowledge** *("to know")* reflects the characteristic trends of competence-oriented education through the scientific meanings attributed to the university education process, which consists in the development of the capacities to autonomously solve problems in the field of professional activity based on social experiences and of individual experiences; by organizing the education process and creating the conditions for students to experience autonomous solving of cognitive, communicative, managerial, value problems, etc.; through the evaluation of school results consists in assessing the level of training of students' investigative skills.

**2. The stage of functional knowledge** *("knowing how to do")* involves applied, practical activities that transform fundamental knowledge into functional knowledge, also called procedural knowledge. In this case, the students process the information, interpret the assimilated information, ensuring the understanding of the new knowledge. They generate capacities to act/activate in uncertain situations, to translate decisions into actions, to apply, operate and transfer acquisitions, which allow the efficient development of professional activity, the functional use of knowledge and skills in different contexts.

**3. The stage of internalized knowledge** *("knowing how to become")* aims at knowing and understanding life situations, reacting, and acting in unfamiliar situations, and behaving in unfamiliar situations in accordance with one's own way of being. Functional knowledge is internalized at the given stage and becomes abilities, skills, behaviors, and results. The individual stages, taken together, constitute the internal resources that must be mobilized in order to solve a significant situation and serve as the foundation for the formation of professional competences. As a result, the significant situation for the manifestation of these internal resources is unbreakable. A significant situation in professional activity is one that consists of several problem situations and has an inter/transdisciplinary character.

**4. The externalized knowledge stage** entails the transfer of the three types of knowledge activities in the context of "knowing how to become", that is, the resolution of any significant situation. At this stage, the student uses internalized, personalized, conscious, interconnected, hierarchical knowledge to propose and implement his/her own action strategies, develop, and implement a work project, and evaluate and adjust his/her own activities. The “knowing to become” activity is a knowledge process synthesis activity in which the student’s internal resources are externalized through concrete actions performed in a meaningful situation, manifested behavior. In addition to expressing itself through cognitive or actional facts of the students, what essentially defines the formation of research competence is that it invokes continuous organizations/reorganizations of the existing structures of knowledge, abilities, and attitudes.

Assertion students’ personalities in relevant fields: as a social being, as a subject of real-world knowledge, as an active transformer of knowledge, by solving any significant situation, the training of specific competences has respected the levels of training of a specific competence, and it draws prospects for career development [16]:

***The level of knowledge (to know)*** lays the groundwork for the formation and development of the student’s personality and aims at the scientific knowledge system acquired during the learning process. It is based on memorization rather than mobilization of the thinking system. Students retain scientific information but do not grasp the essence of the phenomena being studied.

***The level of application (knowing how to do)*** – this level allows for the application of acquired knowledge in a variety of situations, thereby initiating the development of cognitive capacities for analysis and synthesis.

***The transformational level (knowing how to be)*** enables the development of generalization cognitive processes and the formation of abstract scientific thinking. Creating different transformations and interpretations in your own vision. Development of various research projects.

***Action level (knowing how to become)*** – the science of becoming entails conceptualizing one’s own action strategy, implementing strategies for the development of a self-training project, and putting it into practice by executing and adjusting it. Knowledge aims to integrate the three types of knowledge that can be used to solve problems in various situations; that is, knowing how to become means knowing how to act, resolving any functional situation in professional reality. Each level is divided into three sublevels: minimum, medium, and advanced. The Professional Competences Training Circuit was followed in the training of specific competences.

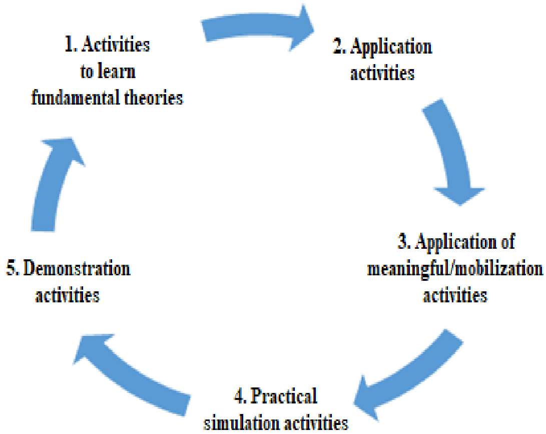


Figure 3.18. The formation circuit of professional competences through training strategies based on research

The training procedure was based on the progressive development of specific competences from level 1 to level 4 (Table 3.10):

Table 3.10. Levels and characteristics of professional research competence

| Levels | Characteristics |
|---|---|
| 1. The level of fundamental knowledge (primarily based on memorization and reproduction). | It focuses on reception, memorization and attention. The student retains the scientific information and does not penetrate into the essence of the problem. He/she defines some notions, facts, laws and reproduces some data. |
| 2. The level of functional knowledge (based on the application of knowledge). | The student applies the acquired knowledge, resorts to perception, sensing through the senses, and looks for a way to operate with the knowledge using thinking, thereby initiating the development of the capacities of analysis, synthesis, and generalization. |

| | |
|---|---|
| 3. The level of internalized knowledge (based on creation). | It is the creative level. The mental processes of analysis, synthesis, generalization are developed and abstract scientific thinking is formed to the extent of individual possibilities, which is based on scientific methodology. |
| 4. Performance level. | The student works independently with internalized, personalized knowledge, externalizing it in significant situations and demonstrating the individual performances attained during the competence formation process. The student can create and implement action plans, as well as plan and carry out activity projects. |

In order to monitor the degree of training of specific competences, the Correlation of the training stages of the professional competences with the evaluation levels was taken into account (Table 3.11).

Table 3.11. Indicators of professional research competence

| No. ord. | Training stages | Assessment level | Sublevels | Indicators |
|---|---|---|---|---|
| **I** | **To know** | ***Knowledge*** | Minimum | Partial acquisition of scientific concepts. |
| | | | Mean | Mastery of all scientific concepts. |
| | | | Advanced | Acquisition of all scientific concepts, logical, systematic ordering, making transfers. |
| **II** | **To know how to do** | ***Application*** | Minimum | Partial use of scientific knowledge |

| | | | | |
|---|---|---|---|---|
| | | | Mean | Using knowledge to solve simple situations. |
| | | | Advanced | Using all acquired knowledge in solving situations. |
| **III** | **To know how to be** | ***Transformation*** | Minimum | Partial awareness of knowledge in solving tasks. |
| | | | Mean | Solving problem-situations, case studies. |
| | | | Advanced | Solving some problem-situations, case studies showing creativity and own vision in presenting the answer. |
| **IV** | **To know how to become** | ***Action*** | Minimum | Operating with internalized, personalized, conscious knowledge. |
| | | | Mean | Proposing and applying own action strategies. |
| | | | Advanced | Elaboration and implementation of a work project, evaluation and adjustment of own activities. |

The current evaluation was carried out through the following methods: systematic observation of the students' working methods, both individually and in groups; oral assessment; assessment of experimental abilities; presentation of chemical experiments; and computer modeling. The students' performances were appreciated for their mental processing of the topic, the studied subject. We list a series of relevant products that can be applied to the evaluation for the interdisciplinary Curriculum: *Chemistry for Life – Integrated Research*: Synthesis table regarding the determination of some coordinating compounds: composition, structure, chemical, physical and biological properties; Synthesis scheme of a new series of coordination compounds based on known organic ligands; Computational modeling; Research project, Synthesis scheme of a new series of coordination compounds based on known organic ligands; Algorithm for estimating the degree of pollution and proposing preventive and protective measures, Analogies, etc. The product is a real, necessary outcome created by the student. One of the labor market's requirements for future specialists is a high motivation for personal development and a respectable attitude toward the work done. Thus, university education, as a result of the pedagogical professionalism of university teaching staff, will provide students with directions for the formation of their individual trajectory of conception and development of their professional career, while also ensuring methodological support in capitalizing on their competences.

We set the goal for the control phase of the pedagogical experiment as determining the level of training of the professional competences required for the chemical student at the control/post-training stage.

The same evaluation benchmark was used, as shown in Table 3.6.

Chemical students' professional competence was evaluated using the following steps: knowledge, capabilities, attitudes/values identifiable with learning activities: knowing, knowing how to do, knowing how to be, and knowing how to become. We identified four categories of indicators that correspond to the stages of competence formation in the assessment of professional competence formation: knowledge (knowing), application (knowing how to do), transformation (knowing how to be), and (action) knowing how to become. Each level is divided into three sublevels: minimum, medium, and advanced. The following methods were used to evaluate the students: systematic observation of their working methods, both individually and in groups; oral assessment; intermediate written assessment; assessment of experimental abilities; presentation of chemical experiments; project presentation; and final exam evaluation.

Evaluation has seen significant conceptual, methodological, and strategic advancements in recent years. This has a significant impact on university education, regulating quality and determining the effectiveness of the educational process. Evaluation is an essential component of any system's operation, as it confirms its level of efficiency. In essence, the evaluation process is complex, consisting of comparing the outcomes of the instructional-educational activity to the planned objectives (quality evaluation), the resources used (efficiency evaluation), or previous results (progress evaluation) [17].

A correct, competent, and effective assessment alters the student's behavior by challenging him to consider his own learning, training, and development activities. Currently, assessment is designed in the context of competence. The evaluation from the perspective of competences entails: shifting the evaluation from the verification and appreciation of results to the evaluation of the process, of the successful learning strategy; in addition to cognitive acquisitions and other indicators, taking into account: personality, attitudes; practical application of what was learned; diversification of evaluation techniques and their suitability to concrete situations; opening the assessment to life; emphasizing self-assessment techniques.

The focus of the educational process on competences formation has an obvious impact on the results evaluation system so that the competence becomes a product of the educational process and becomes the object of the school evaluation. In this sense, G. Meyer states that it is not the behaviors that we evaluate, but the products of those behaviors. We do not evaluate competences, but results, visible traces of these competences [18].

The quality of the modern educational process is determined by the positive nature of the evaluation, the student's motivation for self-evaluation of competences formation progress, and the student's orientation toward success. This stage is critical in the teaching-learning-evaluation triad because it has the intended effects on those involved in the process.

In the context of a competence-based curriculum, the evaluation process will be as personalized as possible, focusing on the student's interests and success. It is critical to encourage students to self-assess and peer-assess. This approach will assist them in becoming aware of their own training requirements, as well as in developing an interest in learning through the acquisition of knowledge, abilities, and attitudes.

We also present some experimental evidence related to the performance indicators that were capitalized in the experiment.

In the control stage, 31 students took part, which also included an 8-item questionnaire, and the results of the evaluation are reproduced in Table 3.12 and illustrated in Figure 3.19.

Table 3.12. Final assessment results (after finishing the optional course)

| Competence | Item | Year of study | Studens, no. | | | Evaluation grade % |
|---|---|---|---|---|---|---|
| | | | Level I | Level II | Level III | |
| investigation; communication | 1. Describe some coordinating compounds met in nature known to you. | I | 12 | | | 100 |
| | | | | 7 | | 50 |
| | | | | | 2 | 25 |
| | | II | 10 | | | 100 |
| | | | | - | | - |
| | | | | | - | - |
| investigation; communication | 2. Argue the importance of some elements (metals) of vital importance in physiological processes. | I | 17 | | | 100 |
| | | | | 4 | | 50 |
| | | | | | - | - |
| | | II | 8 | | | 100 |
| | | | | 2 | | 50 |
| | | | | | - | - |
| investigation; communication | 3. Describe some instrumental methods for determining the composition and structure of chemi-cal compounds. | I | 7 | | | 100 |
| | | | | 14 | | 50 |
| | | | | | - | - |
| | | II | 5 | | | 100 |
| | | | | 5 | | 50 |
| | | | | | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| investigation; communication | 4. Exemplify the importance of using contemporary instrumental methods for determining the quality of pharmaceutical, food and industrial products. | I | 13 | | | 100 |
| | | | | 6 | | 50 |
| | | | | | 2 | 25 |
| | | II | 7 | | | 100 |
| | | | | 2 | | 50 |
| | | | | | 1 | 25 |
| digital | 5. Describe some software specific to the field of Chemistry. | I | 17 | | | 100 |
| | | | | 4 | | 50 |
| | | | | | - | - |
| | | II | 7 | | | 100 |
| | | | | 3 | | 50 |
| | | | | | - | - |
| investigation; ecological | 6. Explain the utility of using specialized digital applications in determining the quality of environmental factors. | I | 15 | | | 100 |
| | | | | 6 | | 50 |
| | | | | | - | - |
| | | II | 9 | | | 100 |
| | | | | 1 | | 50 |
| | | | | | - | - |
| digital; communication | 7. To what extent could the use of different software, special programs, digital applications motivate the chemistry training process? | I | 14 | | | 100 |
| | | | | 7 | | 50 |
| | | | | | - | - |
| | | II | 9 | | | 100 |
| | | | | 1 | | 50 |
| | | | | | - | - |
| investigation; communication | 8. Based on the relationship: *composition →* | I | - | | | - |
| | | | | 19 | | 50 |
| | | | | | 2 | 25 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | *structure →* | II | - | | | - |
| | *properties →* | | | 8 | | 50 |
| | *practical importance*, make an analysis algorithm on a concrete case. | | | | 2 | 25 |

As a result of the questionnaire analysis at the control (training) stage, we discovered that the answers from level III are practically non-existent, except for (2 answers to item 1, year I; 2 answers to item 4, year I; 2 answers to item 8, year I and 1 answer to item 4, year II; 2 answers to item 8, year II).

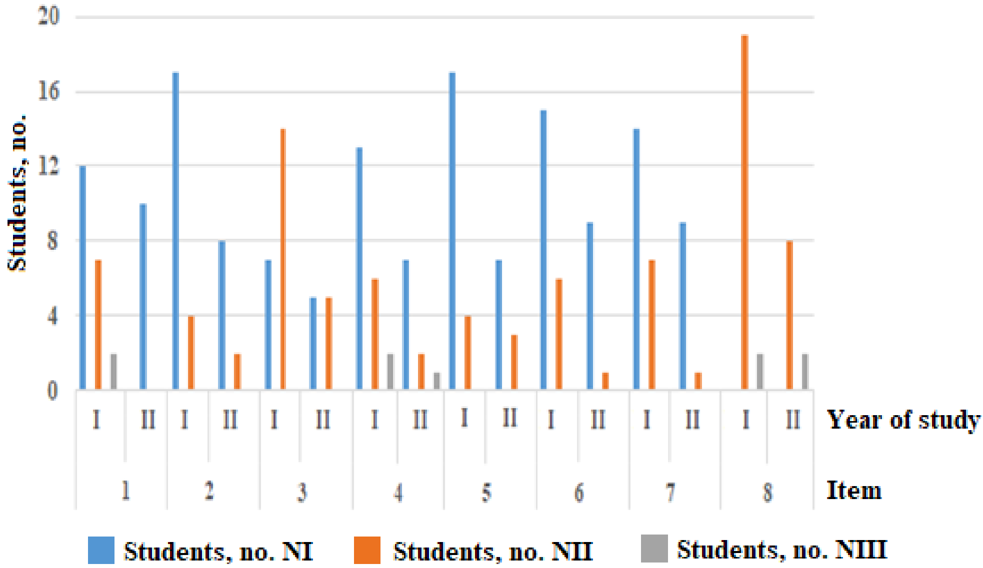


Figure 3.19. Results of the final evaluation (control stage)

As a result, both first- and second-year students focused primarily on level I and level II. In comparison to the ascertainment stage, the answers are more profound, conscious, logical, and pertinent. As a result, we found the motivational component, that is related to professional orientation awareness, motivation, and interest in the field of chemistry, the development of future chemists' creativity, and lifelong learning. The quality of theoretical and practical knowledge formed and developed during the course reflected the cognitive component; the action component reflected understanding and forecasting different actions, the ability to make decisions, and interpersonal communication. The reflective component manifested itself as the ability to consciously solve certain problem situations, the ability to evaluate one's own results and the learning process, and the ability to reproduce experience as a result of the initial training. The following are some of the most pertinent student responses from the control stage: For example, in item 1 – hemoglobin, which contains the $Fe^{2+}$ ion and is found in animal blood and has the function of transporting oxygen to cells and tissues; chlorophyll, which contains the $Mg^{2+}$ ion and is found in plant tissues and participates in photosynthesis. In item 2, the vast majority of respondents (first year, 17 people (level I), 4 subjects (level II); second year 8 persons (level I) and 2 students (level II)) argued the importance of certain metals in physiological processes arguing: Calcium (Ca) – ensures normal functioning of the osteoarticular system, bone density, muscle and bone cells; copper (Cu) – participates in hemoglobin and erythrocyte formation, facilitating iron (Fe) absorption; magnesium (Mg) – participates in protein synthesis, cardiac rhythm regulation; potassium (K) – during fruit ripening. In the case of item 3, several people (7 students of the first year, 5 persons of the second year) described the analysis methods at level I, while the rest only named them (level II, 14 people, first year; 5 people, second year). In item 4, most students (13 people, first year; 7 people, second year) exemplified the importance of using instrumental methods of analysis at level I naming them as are fast, accurate, and sensitive, that can perform an analysis in a short time and with accuracy. The answers to item 5 are practically the majority at level I (17 people, first year; 7 people, second year), where the students named and explained the usefulness of some chemistry-specific software, such as: ChemBio, ChemDraw in the representation of molecular formulas and structure of chemical compounds, ChemCraft, GAMESS, GAUSSIAN for modeling and visualization of molecules in 3D, the rest just named them, level II (4 people, first year; 3 – second year). The usefulness of using digital applications in determining the quality of some environmental factors (item 6) was found in the answers to level I (15 people, first year; 9 people – second year), who argued that they are easy to use, offer the possibility of connecting to a computer and allow the determination of environmental factors quite quickly, both in laboratory conditions and in the field, the rest had answers to the level II (6 people, first year; 1 person – second year), having less reasoned answers. For item 7, the students mostly answered at level I (14 people, first year; 9 people – second year), where they discovered that the special programs, software used in the chemistry training process, together with digital competence, lead to the formation of specific chemistry competences, motivates pupils/students in chemistry lessons, and develops creativity; the rest answered at level II (7 people, first year, 1 person – second year) said it is good to use, but without any explanation. For item 8, no answers were found for level I; however, most of them were for level II (19 people, first year, 8 people – second year) and contained a description of the relationship *composition → structure → properties → practical importance*, well argued, but not on a concrete case. We have two answers to level III in both years I and II, where even the description of the relationship was less contested.

Two current evaluations and the final evaluation were carried out within the free-choice course *Chemistry for Life – Integrated Research* to demonstrate the effectiveness of the developed model and the proposed methodology in the process of implementing them in teaching, and the results obtained were statistically analyzed with the help of t-Student tests (for paired samples) and Wilcoxon (ranks test) [19].

Since the free-choice course *Chemistry for Life – Integrated Research* was only experimentally implemented in a group of students who studied it voluntarily, the Student t-test for paired samples was used to compare scores to a variable in different experimental conditions. The following conditions are met for this test: the dependent variable (test grades) is quantitative; the dependent variable is normally distributed (Figure 3.20); the independent variable (subjects of the experimental sample) is dichotomous, and the groups are pairs (the same subjects in different experimental situations).

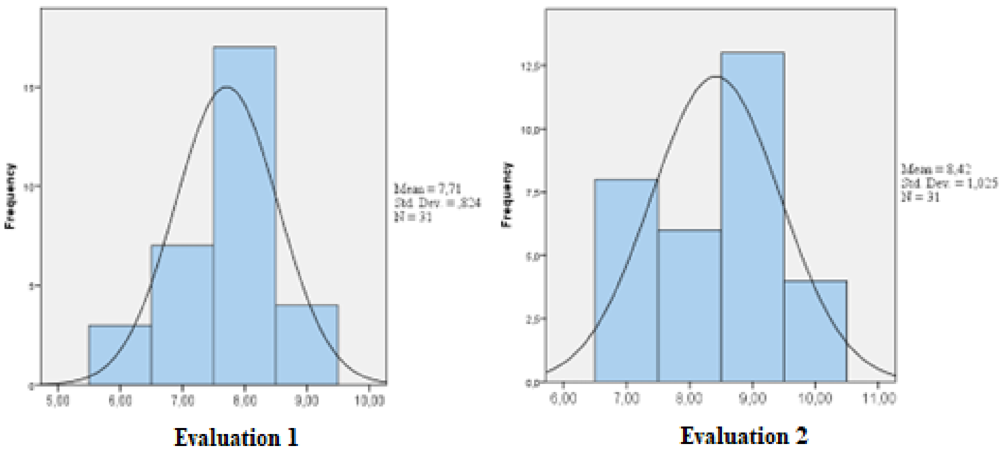


Figure 3.20. Normal distribution of results in evaluation I and II

Below we present the results of the t-Student test to compare the results of assessment I with those of assessment II.

Table 3.13. Student t-test for Paired Samples:
Evaluation 1 – Evaluation 2 Paired Samples Statistics (1)

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | evaluation grade 1 | 7.7097 | 31 | 0.82436 | 0.14806 |
| | evaluation grade 2 | 8.4194 | 31 | 1.02548 | 0.18418 |

Paired Samples Correlations (2)

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | evaluation grade 1 & evaluation grade 2 | 31 | 0.819 | 0.000 |

Paired Samples Test (3)

| | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | Lower | Upper | | | |
| Pair 1 evaluation grade 1 evaluation grade 2 | -0.70968 | 0.58842 | 0.10568 | -0.92551 | -0.49384 | -6.715 | 30 | 0.000 |

The first table (Paired Samples Statistics) shows the means, number of subjects, standard deviations, and standard errors of the means for each of the two variables. The average for evaluation I is 7.7, and the average for evaluation II is 8.4. The second table (Paired Samples Correlations) displays the correlation coefficient between the variables evaluation grade 1 and evaluation grade 2, with $r = 0.819$ and the associated significance threshold $p<0.001$, indicating that the two variables have a positive correlation. The third table (Paired Samples Test) shows the main results of the t-test, which are statistically significant: $t = 6.715$, $p<0.001$. These results show a significant difference between evaluation I and evaluation II, with the mean from evaluation II being significantly higher than the mean from evaluation I. The significance of the difference between the means is also confirmed by the fact that the difference (0.7) lies between the limits of the confidence interval (with a probability of 95%), interval that does not contain the value zero. The magnitude of the effect (d) can be calculated using the obtained results:

$$d = \sqrt{\frac{t^2}{df}} = \sqrt{\frac{t^2}{N-1}} = \sqrt{\frac{6{,}715^2}{31-1}} = 1.2 \qquad (3.1)$$

Since d≥1, it follows that the experimental approach had a very strong effect on increasing learning outcomes from the first assessment to the second.

The same test was also applied to compare the results of the I and the final assessment, and the results obtained are illustrated in Table 3.14.

Table 3.14. Student t-test for paired samples: evaluation 1 – final evaluation

Paired Samples Statistics (1)

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | evaluation grade 1 | 7.7097 | 31 | 0.82436 | 0.14806 |
| | final evaluation grade | 8.2194 | 31 | 0.74360 | 0.13356 |

Paired Samples Correlations (2)

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | evaluation grade 1 & final evaluation grade | 31 | 0.803 | 0.000 |

Paired Samples Test (3)

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | evaluation grade 1 final evaluation grade | -0.50968 | 0.49756 | 0.08937 | -0.69219 | -0.32717 | -5.703 | 30 | 0.000 |

In this case (the average at the first evaluation is 7.7, and the average at the final evaluation is 8.2194), there is a positive correlation between the two variables ($r = 0.803$, $p<0.001$), and the t-test results ($t = 5.703$, $p<0.001$) show a difference between the results at the evaluation I and the final evaluation, with the average from the final evaluation being significantly higher than the mean from the evaluation I. The effect size (d) can be calculated using the obtained results:

$$d = \sqrt{\frac{t^2}{df}} = \sqrt{\frac{t^2}{N-1}} = \sqrt{\frac{5{,}703^2}{31-1}} = 1.04 \qquad (3.2)$$

The effect size calculated according to the obtained results is d=1.04 (≥1), which indicates that the experimental intervention had a *very strong* effect on increasing learning outcomes from the first to the final evaluation.

Another situation is evidenced in the results of the t-Student test for paired samples, when we compare the means at the evaluation II and the final evaluation (Table 3.15).

Table 3.15. Student t-test for paired samples: evaluation 2 – final evaluation

Paired Samples Statistics (1)

| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | evaluation grade 2 | 8.4194 | 31 | 1.02548 | 0.18418 |
| | final evaluation grade | 8.2194 | 31 | 0.74360 | 0.13356 |

Paired Samples Correlations (2)

| | | N | Correlation | Sig. |
|---|---|---|---|---|
| Pair 1 | evaluation grade 2 & final evaluation grade | 31 | 0.846 | 0.000 |

Paired Samples Test (3)

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | | | |
| | | | | | Lower | Upper | | | |
| Pair 1 | evaluation grade 2 final evaluation grade | 0.2000 | 0.56095 | 0.10075 | -0.00576 | 0.40576 | 1.985 | 30 | 0.056 |

We note that although there is a positive correlation between the researched variables (evaluation grade 2 and final evaluation grade) r = 0.846 and p<0.001, however this is a very strong one. The results of the t-test (t =1.985, p=0.056 (>0.05)) are statistically insignificant, indicating that the means at the evaluation II and the final evaluation do not differ significantly from each other. The non-significant difference is also confirmed by the fact that (with 95% probability) the confidence interval (-0.005; 0.405) contains the value zero.

This finding can be explained by the fact that the topics included in the final assessment refer to the entire course content and contain a large volume of information, which requires highly developed learning skills or is difficult to achieve during a completely new course.

$$d = \sqrt{\frac{t^2}{df}} = \sqrt{\frac{t^2}{N-1}} = \sqrt{\frac{1.985^2}{31-1}} = 0.36 \qquad (3.3)$$

The size of the effect d=0.36, is between 0.2 and 0.5, which indicates that the effect of the intervention program on the decrease of the mean from the evaluation II to the final evaluation is a weak one.

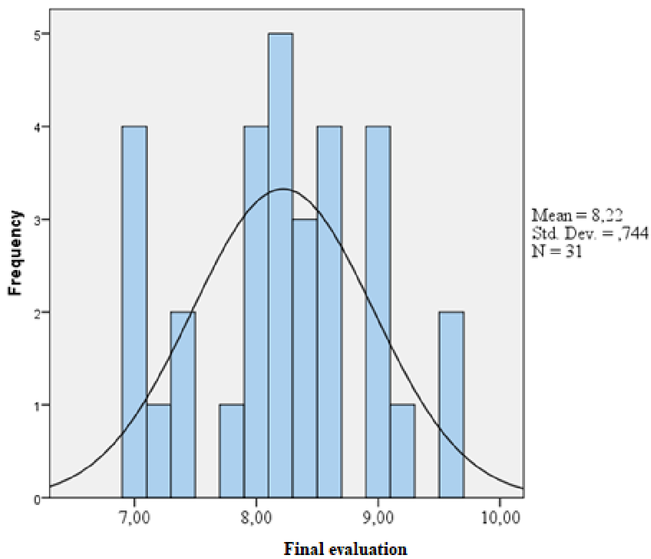


Figure 3.21. Normal distribution of results at the final evaluation

The t-test results, on the other hand, may not be conclusive in this case because the final grade variable is not normally distributed, as shown in the figure 3.21 (it does not fall under the normality curve) and these results will be challenged by another statistical test that is more robust to the normality of the distribution.

The specialized literature recommends using at least one more statistical test to confirm the obtained results described above, and in the case of the current study, the Wilcoxon test was used to compare two paired variables, because the experimental sample has a relatively small number of subjects and the minimum test performance requirements are met: the samples are paired, and the dependent variable is quantitative [10]. The Wilcoxon test, like the Mann-Whitney test, is based on comparing the means of the ranks, but the ranks are determined by the difference between the scores of the examined variables for each subject, considering the sign of the difference (positive or negative). This test determined whether the application of the developed methodology on an experimental group of 31 students resulted in the registration of academic success from the first to the final assessment.

The Wilcoxon test for two paired variables was used in the same way as the Student t-test to compare the results of evaluation I and evaluation II (Table 3.16), evaluation I and the final evaluation (Table 3.17), and evaluation II and the final evaluation (Table 3.18).

Table 3.16. Wilcoxon test for evaluation 1 – evaluation 2

Ranks (1)

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| evaluation grade 2 evaluation grade 1 | Negative Ranks | $2^a$ | 13.50 | 27.00 |
| | Positive Ranks | $24^b$ | 13.50 | 324.00 |
| | Ties | $5^c$ | | |
| | Total | 31 | | |

a. evaluation grade 2 < evaluation grade 1
b. evaluation grade 2 > evaluation grade 1
c. evaluation grade 2 = evaluation grade 1

Test Statistics[a] (2)

| | evaluation grade 2 - evaluation grade 1 |
|---|---|
| Z | $-4.315^{b}$ |
| Asymp. Sig. (2-tailed) | 0.000 |

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

The Ranks table displays the sum and average of the positive and negative ranks based on the number of subjects specified (only two negative ranks are recorded). The main test results are reflected in the Test Statistics table, and because $z = -4.315$ and $p<0.001$, there are significant differences between the means of evaluation I and evaluation II. The significance of the difference is determined by examining the sum of the ranks in the Ranks table.

The maximum value corresponds to positive ranks and is 324.00, indicating that there are significantly more situations in which the evaluation II grade is higher than the evaluation I grade (24 versus 2).

According to these findings, the effect size is:

$$r = \sqrt{\frac{z^2}{N}} = \sqrt{\frac{4.315^2}{31}} = 0.775 \qquad (3.4)$$

and since it is greater than 0.7 (according to Cohen's reference values), the effect is very strong.

These findings confirm the t-Student test results, indicating that academic success was maintained from the first to the second assessment, and the experimental intervention based on the developed methodology had a positive effect.

Table 3.17. Wilcoxon test for evaluation 1 – final evaluation Ranks (1)

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| final evaluation grade - evaluation grade 1 | Negative Ranks | 3[a] | 10.67 | 32.00 |
| | Positive Ranks | 26[b] | 15.50 | 403.00 |
| | Ties | 2[c] | | |
| | Total | 31 | | |

a. final evaluation grade < evaluation grade 1
b. final evaluation grade > evaluation grade 1
c. final evaluation grade = evaluation grade 1

Test Statistics[a] (2)

| | final evaluation grade - evaluation grade 1 |
|---|---|
| Z | -4.042[b] |
| Asymp. Sig. (2-tailed) | 0.000 |

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Table 3.18 shows the results that confirm the findings following the application of the Wilcoxon test for the evaluation I and the final evaluation, namely ($z = - 4.042$, $p < 0.001$) that there are significant differences between the mean from the evaluation I and the mean from the final evaluation, in favor of finally, because the sum of the highest ranks is 403.00 and corresponds to positive ranks, and the effect is very strong ($r=0.726 \geq 0.7$).

$$r = \sqrt{\frac{z^2}{N}} = \sqrt{\frac{4.042^2}{31}} = 0.726 \quad (3.5)$$

Table 3.18. Wilcoxon test for evaluation 2 – final evaluation

Ranks (1)

| | | N | Mean Rank | Sum of Ranks |
|---|---|---|---|---|
| final evaluation grade - evaluation grade 2 | Negative Ranks | 13[a] | 11.27 | 146.50 |
| | Positive Ranks | 6[b] | 7.25 | 43.50 |
| | Ties | 12[c] | | |
| | Total | 31 | | |

a. final evaluation grade < evaluation grade 2
b. final evaluation grade > evaluation grade 2
c. final evaluation grade = evaluation grade 2

Test Statistics[a] (2)

| | final evaluation grade - evaluation grade 2 |
|---|---|
| Z | -2.106[b] |
| Asymp. Sig. (2-tailed) | 0.035 |

a. Wilcoxon Signed Ranks Test
b. Based on positive ranks.

Table 3.18 refers to a comparison of the evaluation II and final evaluation results, an analysis that, in the case of the t test, did not reveal any significant differences. This time, because z = - 2.106 and p = 0.035 (<0.05), it revealed that there are significant differences between the grades from the second and final evaluations. The significance of the difference is highlighted by an examination of the Sum of Ranks in the Ranks table, which confirms that the highest value is 146.50 and corresponds to negative ranks, i.e. situations in which the ranks of the evaluation II variable are higher than the ranks of the final evaluation variable.

$$r = \sqrt{\frac{z^2}{N}} = \sqrt{\frac{2.106^2}{31}} = 0.378 \qquad (3.6)$$

However, unlike the t-test, the size of the effect $r = 0.378 \geq 0.3$, indicates that there is an average effect of the intervention program on the decrease of the average at the final evaluation compared to the evaluation II.

In conclusion, we can state that the experimental intervention to implement the model and methodology developed following the author's pedagogical research had a generally positive effect, demonstrating significant differences between the averages from evaluation I, evaluation II, and the final evaluation (with small exceptions argued above), demonstrating significant academic success for the people involved in the experiment.

In the context of the same phase of the experiment - the control - at the end of the interdisciplinary course *Chemistry for Life – Integrated Research*, we used a questionnaire of 10 questions to determine the students' attitude and level of satisfaction with this course. The survey results are as follows (some of the most relevant responses):

**Item 1: Do you believe that integrated knowledge is required for the study and comprehension of chemical phenomena and processes? Why?**

- yes, integrated knowledge is necessary, because it allows us to understand the chemical phenomena and processes that occur between substances;
- improves the chemistry training process;
- because we see and understand some phenomena from multiple perspectives;
- because it broadens the area of knowledge and understanding of chemistry;
- because chemistry is found in the vast majority of products in everyday life;

- because each chemical process/phenomenon cannot exist independently of other phenomena: physical, biological;
- enhances the chemistry training process by referring to related disciplines;
- because they broaden our knowledge in the field, prepare us professionally, and we understand chemistry more deeply;
- stimulates us to know chemistry better;
- because biology, physics, mathematics, and other disciplines complement chemistry;
- because they will help us understand chemical processes and broaden our professional horizons.

**Item 2: Would such interdisciplinary studies help future chemists with their initial professional training? Explain.**

- it would contribute significantly because specialist training must be multilateral, raising the general level of knowledge and application of the skills learned;
- it would contribute by having a unique in-depth character;
- any discipline studied contributes to the professional training of the future chemist, especially interdisciplinary ones, allowing the realization of a potential for success in the chosen career;
- because a science cannot exist apart from other sciences;
- of course, this allows for the improvement of knowledge as well as the broadening of their application area;
- because they offer them the development of the field in which he operates and simplify his work;
- because they are useful during professional training;
- because these interdisciplinary studies contribute to the initial professional training by becoming more in-depth in the field and you have a greater baggage of information;
- because they are complementary in order to deepen the specialty;
- opens up new perspectives on chemistry and analysis methods;
- because the disciplines complement each other and such studies contribute to the professional training of future chemists;

- because the combination of disciplines completes the body of knowledge;
- it offers other possibilities and visions for the deeper understanding of chemistry.

**Item 3: Do you believe that using a computer in practical work makes Chemistry more motivating? Why?**

- allows visualization of the structure of chemical compounds;
- various programs/software make our work easier, help us in practice, thus making chemistry more effective and motivating;
- chemistry without a computer would be impossible, because we can draw, model, transcribe chemical formulas, etc. with its help;
- because you can get involved personally;
- because it allows visualization of the structure of the compounds;
- viewing some 3D images makes it easier to notice and understand some things;
- to apply some knowledge in a different way;
- we learn knowledge in a different form;
- because students contribute imagination and ingenuity;
- simplifies education;
- it allows us to reproduce some aspects that were only on an imaginary level, through schemes, structures, and reactivity;
- I can apply the knowledge acquired in courses more easily;
- students enrich their imagination, have curiosity and ingenuity, and are even more motivated;
- it is a useful and helpful tool that opens up new opportunities;
- we integrate digital competence with some chemistry-specific competences.

**Item 4: How would you use physical methods of analysis to determine the composition and structure of compounds?**

- infrared (IR) analysis, nuclear magnetic resonance (NMR);
- IR and NMR, because they are modern, quick, and accurate methods;
- spectrophotometry;
- thermal analysis
- spectrophotometry;
- X-ray diffraction.

**Item 5: Do you believe that knowledge from related fields such as biology, physics, computer science, and mathematics is necessary for a chemist's professional training? Why?**

- all of these related fields can be applied in chemistry, allowing the young specialist to have integrated, in-depth knowledge in the field of chemistry;
- a greater area of knowledge in different fields is always an advantage, because in professional training we collide with different questions that require information from these fields;
- this knowledge can be applied in chemistry for the more complex analysis of compounds;
- as a result, a chemist's training becomes more in-depth;
- because they lead to the discovery of new perspectives on some compounds;
- the knowledge received is applied in practice, allowing a chemist's professional training;
- knowledge from related fields applied in chemistry allows a specialist to possess integrated, in-depth knowledge in chemistry;
- are required to explain a process or phenomenon;
- provides new opportunities and facilitates the educational process;
- yes, because each discipline complements one another;
- because to explain chemical processes/phenomena, a chemist must involve methods and techniques specific to other disciplines;
- because some integrated/interdisciplinary studied processes are easier to understand;
- contributes to effective professional training;
- knowledge from various fields will result in a well-trained and informed chemist.

**Item 6: Will studying this discipline help a future chemist's professional training? By what criteria?**

- by knowing the methods of analysis;
- because by using different methods and complementing chemistry with other sciences, it becomes more interesting;

- through this discipline, we train professionally as future chemists, because we were given additional information regarding the areas of application of analysis methods;
- because I know more information that will help me implement some software and methods;
- all disciplines are necessary in the professional activity;
- initiates the in-depth study from synthesis → structure → properties → application;
- it gives us new knowledge in the field of chemistry and not only;
- by integrating into the world of technologies and virtual analysis methods;
- by developing specific chemistry skills;
- by integrating into the world of technologies and virtual analysis methods;
- because the explanation of a process or phenomenon is easier and simpler to understand;
- because a competent chemist must know and understand modern analysis and modeling methods to carry out research in the field of chemistry;
- develops certain chemistry competences;
- opens up other opportunities for professional and social integration.

**Item 7. Which module, in your opinion, motivated you the most and why?** Some of the student responses are listed in Table 3.19 and shown in Figura 3.22.

Table 3.19. Student preferences for curriculum modules

| Module | Preferences |
|---|---|
| **1. Obtaining compounds with useful properties** (4 persons, 12.9%) | - I found out some ligand synthesis methods;<br>- I learned about a variety of coordination compounds and their fields of application, as well as coordination compound synthesis methods and ligand synthesis. |
| **2. Instrumental methods for analyzing the composition and structure of compounds** (8 persons, 25.81%) | - I learned about some methods for determining the structure and composition of compounds;<br>- we can appreciate at a higher level the structure and properties of compounds. |
| **3. Methods for modeling the composition and structure of compounds** (19 persons, 61.29%) | - through modeling we can observe the structure of the substance;<br>- we learned about different programs that allow us to model compounds and visualize them in 3D;<br>- because it is necessary to combine the computer with different software specific to chemistry;<br>- I learned different modeling methods that I will apply in the future. |
| **4. Ecological audit and ways to determine the quality of environmental factors (use of sensors)** (3 persons, 9.68%) | - elaboration of experiments with Neulog sensors;<br>- the Neulog application is easy to use, fast and allows use both in the laboratory and in the field. |

For this item, the majority opted for one module, and three students for 2 modules.

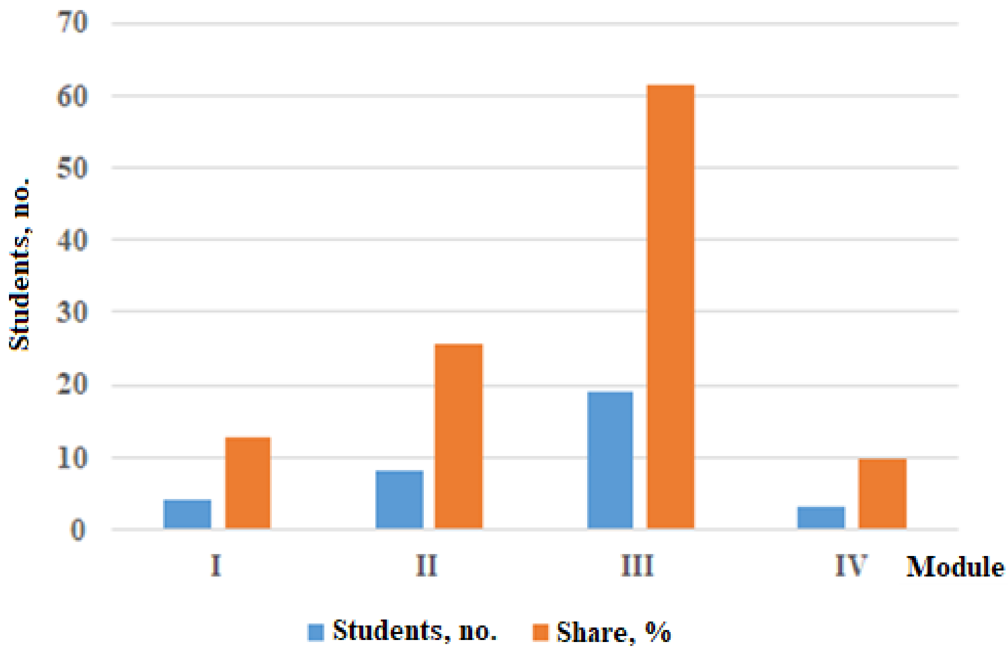

Figure 3.22. Share of preferences

**Item 8: In your opinion, how can the chemistry training process be improved to make the discipline more motivating:**

- to apply all the theory in practice,
- more devices for using or putting into practice the knowledge;
- more practical activities and to integrate study with research;
- I think that only the students' attitude towards discipline should be changed;
- chemistry must be studied and included in each subject, with different interesting and motivating topics;
- going out into the field, trips to factories and plants;
- active involvement of ICT, practical activities, interdisciplinarity.

**Item 9: In your opinion, what is necessary for the development of a chemist's initial professional competence:**

- interdisciplinarity is required.
- a lot of experience and a lot of baggage of initial knowledge that was later deepened;
- in-depth knowledge of chemistry and related fields;

- the ability to use interdisciplinary links;
- knowledge application in practice;
- additional, individual knowledge;
- a stable base in the practical field and diligence;
- theoretical and practical instruction;
- the formation and understanding of complex processes from an interdisciplinary perspective;
- to integrate interdisciplinary links, which will help us grow in knowledge and evolve;
- integrated study of related disciplines;
- knowledge of digital software, analytical abilities,
- analytical abilities, practice and initial knowledge.

**Item 10: Share your thoughts on the interdisciplinary curriculum *Chemistry for Life – Integrated Research*:**

- it was an interesting course so I learned some modern methods of analyzing chemical compounds;
- I gained interdisciplinary knowledge, each module was exciting, and the knowledge gained will be applied later;
- I learned some methods of modeling chemical compounds, the use of Neulog sensors and other knowledge that will be used in the future;
- I was initiated into in-depth study, gaining interdisciplinary knowledge, I studied more deeply some chemical processes and phenomena, I got to know some modeling programs that captivated me;
- I expanded my horizon of knowledge in this field so I was motivated to know much more;
- I was satisfied with the quality of this discipline teaching and I believe that it can be a discipline with an impetus in the field;
- it was a welcome course because it allowed us to study chemistry in greater depth and gave us opportunities to study new methods of analysis;
- it was an interesting one, full of useful information, and through it I discovered some characteristics of chemistry, I learned new methods of analysis and modeling of chemical compounds;

- it is a course that contributes to the formation of professional competence;
- I developed a positive attitude, being involved in studies with an interdisciplinary aspect;
- such an integrated curriculum is welcome, as it allows studying chemistry in more depth and provides opportunities to study and apply new methods of analysis unknown until now;
- it was quite effective and interesting and it would be good if it were introduced in the faculty as a compulsory subject;
- such a discipline is welcome because it allows for the comprehensive study of chemical processes.

The interpretation of the results of the questionnaire method and the mathematical-statistical methods of experimental data processing allowed the following conclusions to be highlighted:

1. The results of the observational experiment confirmed that the traditional approach to the contents in the formation of professional competences in chemistry is insufficient; thus, an interdisciplinary model of initial training of chemical students' professional competences is required by integrating the contents of chemistry with biology, physics, informatics, and mathematics.
2. At the ascertainment stage, the level of development of initial professional competences in the experimental sample was relatively low, with answers at levels II (50%) and III (25%) predominating. In most cases, there is a lack of depth in answers, logical thinking, consistency, relevance, and originality of ideas.
3. Following the application of the model of initial professional competences training in an interdisciplinary context, the level of professional competences development increased significantly, with responses at levels I (100%) and II (50%) with a more content predominated deep, conscious, logical, and relevant. As a result, we discovered the motivational component, which is related to professional orientation awareness, motivation and interest in the field

of chemistry, the development of future chemists' creativity, and lifelong learning. The quality of theoretical and practical knowledge formed and developed during the course reflected the cognitive component; the action component reflected understanding and forecasting different actions, the ability to make decisions, and interpersonal communication. The reflective component manifested itself as the ability to consciously solve certain problem situations, the ability to evaluate one's own results and the learning process, and the ability to reproduce experience as a result of the initial training.

4. The effectiveness of content integration in studying the interdisciplinary course *Chemistry for Life – Integrated Research* was demonstrated in the training experiment. We focused on the interdisciplinary integration of contents via the field of direct and indirect correspondence.
5. The realization of the pedagogical experiment enabled the detection of significant changes in the experimental group, where the implementation of the interdisciplinary course increased students' motivation, involvement, degree of collaboration, and academic success.
6. Experimental research is the basic activity in the initial training of chemical students, and the use of modern chemistry-specific information technologies in the training process opens new opportunities in the training and development of professional competences specific to the field, as well as the achievement of individual motivating tasks [20, 21].
7. The effectiveness of content integration in the study of the interdisciplinary course *Chemistry for Life – Integrated Research* was demonstrated during the training stage of the pedagogical experiment [22]. We concentrated on the interdisciplinary integration of contents via the field of direct and indirect correspondence.

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