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Pedagogical and motivational principles of quality assurance of chemical education in technical universities of Ukraine: problems, experience, prospects

Abstract

The purpose of the paper is to consideration of the main motivating factors for ensuring high-quality education of engineers to achieve European standards of higher education based on the analysis of the educational process in the fundamental subject of Chemistry among engineering students at Igor Sikorsky Kyiv Polytechnic Institute over three years (2019, 2020, 2021). The article analyzes the principles of the educational process in the university, identifies the advantages and disadvantages of the modern system of engineering education, proposes motivational factors to improve the quality of education and identifies the main approaches to the formation and development of necessary professional competencies of graduates. *Methodology*. To achieve this goal, theoretical and empirical research methods were used: the method of critical analysis of pedagogical and methodological research papers on the issue; analysis of applicable laws of the Ministry of Education of Ukraine and regulations of the education process in the Igor Sikorsky Kyiv Polytechnic Institute; method of scientific observation of the educational process at the Departments were the authors teach subject "Chemistry" (namely, all of departments of the Institute of Mechanical Engineering: Department of Applied Mechanics, Department of Dynamics, Mechanical Engineering and Support Materials, Department of Machine Design, Department of Technology Machine Construction and some of departments of the Institute of Welding and Material Science: Department of Laser Technology, Department of High Temperature Materials and Powder Metallurgy, Department of Welding). The total number of students who participated in the learning process, the number of attended lectures, consultations, laboratory and practical classes were counted. Questionnaires were also used for students in these departments regarding motivation to study, examination results, difficulties in learning, and communication with teachers. The *aim* of the article is to analyze the experience of modernization of basic chemical education for students of natural sciences, to identify the motivating factors for improving the quality of education at each level – individual, state, university – and to identify the difficulties and ways to overcome them. *Conclusion*. Successful engineering and special training in the system of higher technical education should be based on the scientific basis of the corpus of basic natural sciences. Given the relevance of chemistry in today's reality for the creation and implementation of innovative developments and technologies, the relevance of training in environmental and energy management, sustainable development, the relevance of strengthening the chemical component in the educational and professional training programs of bachelors of engineering is obvious.

Keywords

research institute, quality assurance, motivational factor, higher engineering education

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1 Introduction

One of the main objectives of higher education in Ukraine under the conditions of integration into the European educational space is to ensure the formation of competence-based approach to learning. The modernization of higher engineering education requires revision of the orientation of the educational process from conventional knowledge acquisition to the formation of such a level of fundamental training, which allows an engineer to remain professionally mobile throughout his/her creative career.

An urgent issue is the creation of a mechanism for sustainable development of the education system using a system of motivational factors at each level. At the same time, the task of ensuring modern quality of education on the basis of preserving its solid foundation and compliance with the current and future needs of the individual, society, the state and the European educational space becomes a defining one for educational policy.

The authors who have studied this topic mainly single out 5 personal motivational factors for students to get a quality engineering education: 1 – prestige of engineering education, 2 – professional success, 3 – willingness to solve any problem, 4 – financial security, 5 – opportunity to improve the world (Zubin, 2021). Exploring the essence of motivation, some authors define it as a process by which purposeful activity is activated and supported (Abdelsattar, 2021).

Researchers have come up with a general definition of motivation: it is a mental state that inspires behavior and stimulates the desire to achieve goals (Yukseloglu, 2013). Motivation is also known as an academic interest, which is considered to be the most powerful of all positive influences on student performance. In (Yukseloglu, 2013, Hakan, 2014) it was found that motivation is positively associated with high academic performance and success. Researchers emphasize that academic motivation is the only factor that affects academic performance directly, while other factors do so indirectly. They generally agree that motivation contributes to learning and cognition, as motivated students spend more time on self-study and tend to graduate successfully, while unmotivated students are more likely to drop out. For students, motivation stimulates the acquisition of the necessary qualifications in their careers (Steinmayr, 2019). Motivation determines the reasons for specific behavior: those aspiring to higher education show energy, determination, persistence and consistency. The work of engineers is a priority for the further development of society, so one of the most important among all other tasks that the state should constantly take care of is to organize a system of effective and result-oriented engineering education. The sphere of influence of the state includes both the care for the quality of students' education and equipping teachers with the necessary resources for the educational process (Hakan, 2014). The state should take care of the material support of the academic process in universities, namely: to optimise aspects of the organisation of teachers' work, including setting *workload, working conditions and availability of modern scientific equipment*; regulating motives and incentives for work, including financial issues (increase in salaries and benefits); to solve the problem of attracting young highly qualified staff and creating conditions for the attractiveness of the work of university teachers; to promote the purchase of the latest scientific equipment at the expense of the state, replenishing the laboratory facilities of universities with a view to the future and ensuring the development of modern popular technologies and projects. Moreover, public institutions could create incentive funds (grants, social benefit packages) to finance outstanding engineering graduates who have completed international academic and professional internships under dual degree programs, Erasmus+KA1, KA2, thus providing intellectual capacity for the future economy. The university level of motivation development implies the use of corrective measures by the administration of the educational institution, encouraging teachers to constantly modernize the content of courses and subjects, to use innovative methods and forms of learning, to encourage students to deepen their knowledge, which significantly affects the quality of education. The main motivating factors of a teacher include internal motivation related to doing something to improve their work, academic freedom; competence and kinship with all participants in the educational process (Law, 2010). Teachers should be free to choose methods and ways of conveying technically complex material, provide positive feedback on student performance (praise, identifying fewer mistakes, acknowledging strengths, focus on positives in the student's work) and promote the acquisition of the perfect level of competencies by graduates (Catz, 2017). The level of interest of teachers in their teaching also affects the motivation of students to learn. Teachers who are energetic and passionate about their subject tend to convey positive feelings and the importance of their subject (Schiefele, 2015; Zhang, 2014).

According to the current literature we can see that the problem of introducing motivational factors in improving the quality of education is actively discussed, but separately at each level (individual, university, state). The authors of this study have tried to analyze the problem as a whole, identify the shortcomings and difficulties and find possible ways to overcome them.

2 Hierarchical spiral 'education – science – innovation – new knowledge in education'

To improve the quality of education, it can be modernized by using the following principles of

education: a single educational space; parity of education and upbringing; integration of education and science; academic freedom; unity and degree (transparency) of education for society. The main urgent tasks of the reform should be implemented based on the introduction of a three-tier European education system (Bachelor – Master – PhD), including quality basic and academic training, industry-specific engineering training to develop sufficient professional skills, and an innovative component that lays the foundation for mastering the organizational and managerial tools needed to perform professional tasks.

The implementation of the modern state paradigm of knowledge acquisition and implementation along the hierarchical spiral "education – science – innovation – new knowledge in education" can be ensured on the basis of the fundamental quality of university training by involving the latest scientific achievements in the formation of adequate educational content. Universities should use the scientific achievements of innovative developments and technologies in the educational process, to ensure the provision of integrated knowledge and research-based learning opportunities in all forms. Only in this case students have a strong motivation to learn and develop a creative attitude toward the subjects to be mastered in the learning process. According to the authors, integrated knowledge that ensures the development of new areas and specialties, in particular, given the relevance of training in sustainable development, environmental management, biotechnology, nanotechnology, should include advanced training in the basic natural sciences, especially physics and chemistry. The transition of the Ukrainian system of higher education to European educational standards has changed the target principles of graduate training. Now the purpose of education is to form a set of general cultural and professional competences in students, and the result of educational activities of higher education institutions should be the competence (mastering a list of certain competences) of its graduates. Individual competence is a complex integrated phenomenon, which is a dynamic combination of knowledge, skills, abilities and personal qualities of the subject of educational activity.

Science education is the basic structure of higher technical education, aimed at mastering the methodology of scientific research and the development of general scientific competencies, which are increasingly necessary in the development of modern innovative projects. As Daniel Shechtman, Nobel Laureate in Chemistry, said during a speech at Igor Sikorsky Kyiv Polytechnic Institute in January 2016, "The way to become a true professional is necessarily a broad fundamental training followed by immersion in the relevant professional field."

At the state level, the ***first motivating factor*** to improve the quality of natural sciences education is to ensure the harmonisation of standards of national education with the standards and principles implemented within the European educational space. The implementation of such principles in technical universities allows to guarantee various aspects of graduate training, namely (Zbryts′ka, 2014): worldview level – accumulating knowledge for the formation of a personal view of the world; educational level – obtaining orderly knowledge about the phenomena and laws of nature; subject level – mastering the methodological integrity of disciplines; field level – obtaining the knowledge necessary for mastering the educational material of other subjects; professional level – mastering the subject area of future activities.

In accordance with the Law "On Higher Education", the process of sustainable development of the domestic system of technical education must be urgently implemented. Therefore, the ***second motivating factor*** in the implementation of such an approach is to preserve its strong foundation and compliance with the current and future needs of the individual, society and state. Leading domestic institutions of higher education and science provide continuous training of specialists in three cycles, Bachelor – Master – PhD, by optimized curricula determined by the developed conceptual, methodological principles of the new generation of branch standards of higher education. According to these standards, the competency-based approach is implemented taking into account the trend of changing the nature of work and competency requirements for professionals and the best international practices of educational programs (volume, structure, content) while maintaining the best traditions of domestic education (solid foundation, practical orientation, etc.). That is, the ***third motivating factor*** in ensuring the quality of education is the introduction of a competency-based approach to education as a dynamic function. The main task of engineering education reform is to create conditions and produce specialists with independent critical creative thinking, capable of professional growth and professional mobility in the conditions of informatization of society and development of knowledge-intensive technologies, capable of solving complex issues of innovative development. It is systematic knowledge, understanding of deep multifaceted connections between phenomena and facts that ensure the successful formation of future engineers' ability to find the most effective methods of solving practical problems, promote the development of logical thinking and intuition in working out an acceptable solution.

3 Some problems with the implementation of motivation factors

It is obvious that today, without stopping the trend of reducing the academic hours for natural sciences

in university curricula, it will be problematic to train specialists who must meet the level of competence that ensures the innovative development of society, high-tech business and effective management.

As one of the leading technical universities of Ukraine, the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", is committed to the implementation of an effective quality management system of natural sciences training, including chemistry. The emphasis was shifted to the implementation of person-centered learning, which involves the creation of new organizational forms of interaction between teacher and student, stimulating the active independent acquisition of knowledge, forming professional qualities, skills and abilities for future careers, contributing to increased motivation for learning. The existing system of organization of independent work in the study of chemistry provides independent study of individual sections and topics during extracurricular time, individual homework using adapted author's distance courses, methodological recommendations and manuals compiled by teachers of the department; preparation for laboratory work, including the study of theoretical issues of the relevant section of the subject, which are included in the control questioning as part of the task, as well as the analysis of experiments; study of the sections included in the modular exam and systematization of theoretical material in preparation for the final exam for the course; systematic control and evaluation of the tasks performed by the student independently, obtaining objective information about the level of knowledge of students based on the analysis of the current progress in the E-CAMPUS system; the focus of teachers' advisory activities on managing the formation of cognitive skills in students, taking into account their abilities. However, the organization of extracurricular work on independent assignments, in our opinion, still needs further improvement. It is necessary to find new factors that motivate students for independent quality learning, change approaches and diversify methods of organizing students' independent work. Educational technologies should include the activities of all participants in the educational process to motivate and ensure a high level of performance in accordance with the intended goal, which, in general, is the formation and development of competencies of students and graduates in accordance with the chosen specialty. Trends in the development of education under the Bologna system involve primarily an evolutionary transition from "supportive" learning technologies (traditional educational technologies) to "developing" and "person-oriented" (innovative educational technologies). Traditional educational technologies are mainly focused on the transfer of knowledge and experience of the teacher to the students; it is not required that the knowledge obtained was actually mastered by students and used in the future (Figure 1, Comparative characteristics of educational technologies). The educational process in this case usually takes place within the framework of classical classes, where the teacher takes the position of a "lecturer", and students have to memorize and retell the educational material, solve problems, write tests, module exams, and much more. In such a situation, the student has no incentive to self-education, initiative and independence, as he/she receives all the necessary information from the "lecturer".

In contrast to the traditional learning process, modern innovative technologies force a rethinking of the content of the educational process, which is focused on the formation and development of competencies and competency-based model of a graduate. In this case, students cease to be regular "listeners" and become active participants in the learning process, respectively, the teacher assumes the role of "problem generator", "external consultant", "coordinator". Integrated training cases of video materials (video lectures, video consultations, video laboratory work), created by the teacher, become the main component of distance learning and are used in traditional educational technologies of full-time education.

As a result, students develop new motivational factors that motivate and engage them in quality learning, create more productive ways to achieve a positive result in optimal learning time, and form new competencies through the development of logical thinking and the ability to solve specific practical problems.

The use of modern innovative educational technologies allows the following:

1. Implementing both learning and educational objectives.

In this case, the basic learning objectives of the teacher are the following:

- generalisation, systematisation and deepening of students' knowledge;
- use of personal experience in solving problems considered within the subject area;
- Integration of knowledge from related subjects;
- activation of cognitive activity in students; Formation of teamwork competence (work in mini-groups); Development of students' skills in forming their own arguments and their defence in a discussion;
- stimulating students' ability to identify a problem, set a goal, define tasks and find ways to solve them.

2. Promoting the formation of a new type of student and graduate who has the skills to work independently and is capable of teamwork (directly determined by the main educational objectives, development of activity and independence of students), achieved by the use of modern innovative technologies.

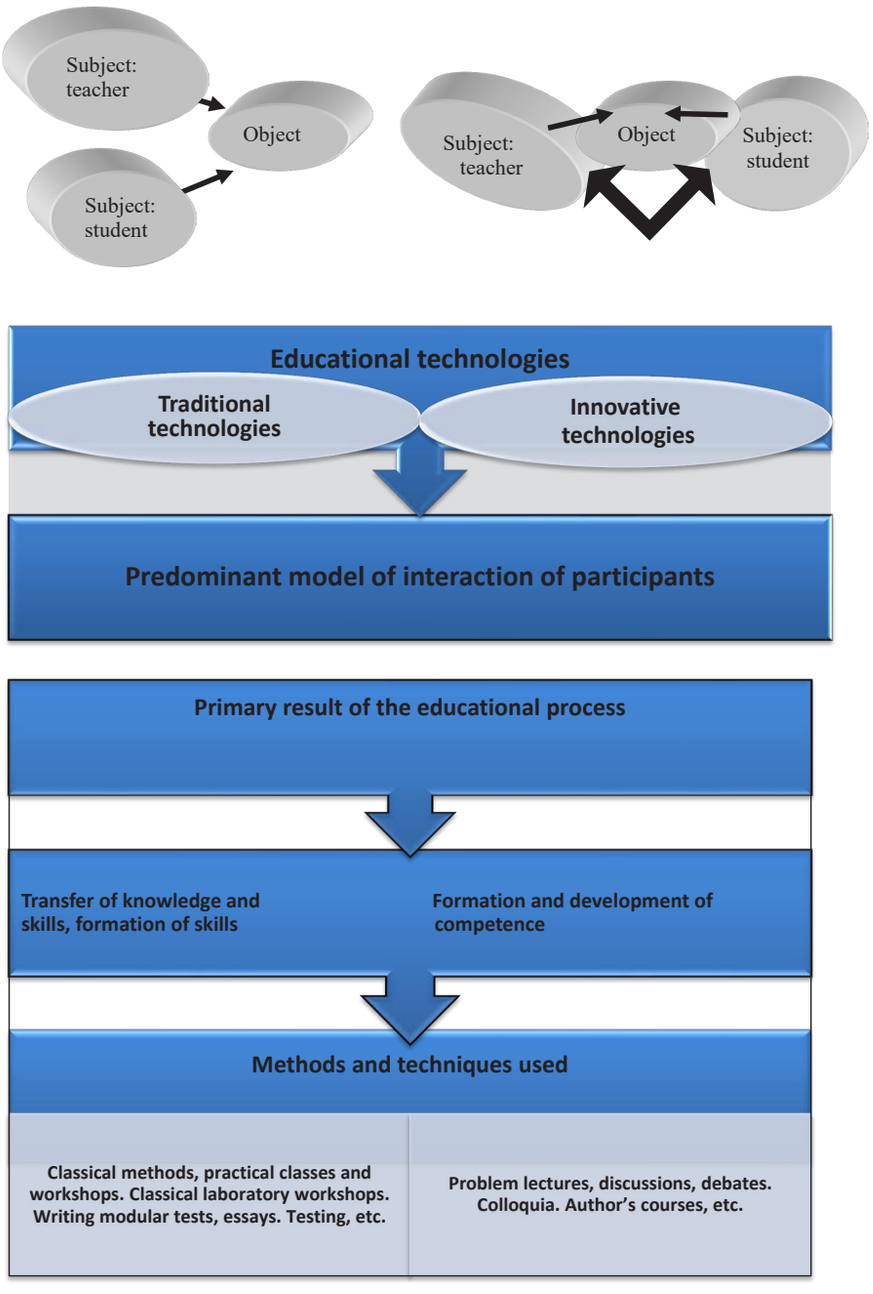

FIGURE 1 Comparison of educational technologies

3. Development of pro-activity, independence and cognitive activities in students.

4. Implementation of an individual and differentiated approach to learning, which should, *inter alia*, be evidenced by the depth of the study of the given subject and, therefore, the level of mastery of certain competencies.

4 Distance learning technologies

The current Law of Ukraine "On Education" defines distance learning as a separate form of education. The current situation with the COVID-19 pandemic and the introduction of quarantine measures in Ukraine have further exacerbated the problem of distance learning. If, until recently, distance learning technologies in Ukrainian universities served mainly to support the traditional educational process, especially for distance learning, now they are becoming the main format (Pidgornyy, 2019).

In particular, the appropriate current level of basic chemistry training as part of the educational process in quarantine during the COVID-19 pandemic was provided through a combination of modern, innovative educational technologies that motivate students to work effectively independently as a key component of fruitful, creative learning.

Overall, in the transition to distance learning 2019–2020 at the end of the semester mastery of the discipline, high performance on the credit module

rating system and the achievement of the index of execution of the curriculum was almost 90%. However, there was a significant decrease in the quality of knowledge. Thus, the number of students who showed satisfactory performance increased to 29%, as the somewhat formalized grading system allows students to get a grade of "satisfactory" or "sufficient" without making the proper efforts in mastering the educational material of the credit module. A significant proportion of students with a "good" grade remained (up to 56%). The number of students who mastered the learning material at the "very good" and "excellent" level increased to 15%.

Similar academic performance in quality chemistry was observed for the two semesters of the following academic year 2020–2021.

Teachers noted that, unfortunately, in the format of distance learning students' independent work often remains uncontrolled and biased due to the lack of teachers' workload of the required number of academic hours for individual consultations, which provide a systematic review of extracurricular work. In addition, the low effectiveness of extracurricular educational work of students due to the improperly formed skills of using educational and methodological literature, electronic sources of information; insufficient ability to plan their free time; habit of cheating in high school; inability to give reasoned answers to questions that require logical thinking; lack of skills to creatively master theoretical material and inability to find solutions to individual practical problems, using the knowledge of natural sciences.

At the same time, there were some shortcomings in the implementation of modern educational technologies in the educational process. This was due to the following:

- lack of qualifications, experience, and teaching skills;
- the complexity of using modern educational technology, given the need for a radical restructuring of credit modules of academic subjects and the constant alternation of the techniques (means) and methods of teaching;
- lack of clear ideas about achieving the required learning outcomes (in particular, the existing competencies);
- insufficiently formed or lacking tools for assessing learning outcomes (i.e. competencies) in the application of modern technologies; subjective factors (lack of time, lack of computers and the ability to use interactive methods of communication (Zoom, Google Meet, Telegram channels, chats, learning platforms such as Moodle, G Suite) in all subjects of the educational process, inefficient academic schedule.

No doubt, the possibilities of using these modern educational technologies are not exhausted and will be supplemented and improved as they are actively implemented and mastered. Thus, the authors believe that maintaining the high quality of engineering education will be accompanied by the development of innovative technologies, such as problem-based lectures, discussions, debates, colloquia, author courses, project research, mastering scientific thinking, presenting results and perspectives, linking results of specific activities with opportunities to use them in professional activities, etc.

5 Conclusions

The quality of national technical education can be ensured with an optimal ratio of the amount of fundamental and academic knowledge with the latest achievements of the creative component of learning, namely, the ability of graduates to perform complex tasks within their industry, taking into account the ability to systematically assess all the consequences of certain management decisions, providing the conditions for sustainable development of society.

Overcoming the main contradictory trends in education due to globalization and transformation of society, as well as the system of values, urgently requires the organization of a multi-component educational process using modern innovative educational technologies to ensure the formation of qualified engineering personnel.

Successful engineering and profile training in the system of higher technical education should be based on the scientific base of the corpus of fundamental natural sciences. Given the relevance of chemistry in modern realities for creating and implementing innovative developments and technologies, the relevance of training in environmental and energy management, sustainable development, the relevance of strengthening the chemical component in the educational and professional training programs for bachelors of engineering is obvious.

The experience of implementing corrective principles for the chemistry teaching process allows for significant constructive gains in quality undergraduate education, but teachers should focus in the future on managing such processes as:

- acquisition of new knowledge through the development of logical thinking of students;
- formation of students' skills of independently solving specific practical problems, the ability to find optimal methods for solving problems;
- development of the ability to analyze in detail the results of research and the ability to obtain an acceptable engineering solution based on the application of known algorithms, principles of analogy;
- improving methods of monitoring independent academic work and ensuring effective individual consultation activities between the teacher and students;
- use of the combined learning environment and project approach to learning.

The application of such teaching methods in the educational process will provide a qualitative component of fundamental knowledge, which is the basis of professional competence, while creating favorable conditions for the development of skills to solve complex engineering and research problems in the dynamic world of technology.

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