

## 1.4 FEATURES OF TRAINING FOR BACHELORS IN COMPUTER SCIENCES IN UNIVERSITIES OF UKRAINE

**Introduction:** It is difficult to imagine a world without information technologies nowadays. ITs are in a public life, in every branch of economy and production. The Law of Ukraine "On the Basic Principles of the Information Society Development in Ukraine for 2007-2015" emphasizes "Information technologies are an instrument of country's social development" (2007). IT development is based on the training of highly qualified specialists. "Training of highly qualified specialists capable to develop new IT and effectively use them in practice, becomes strategically important" (Kovaliuk, 2011, p. 293). Economic development depends on how effective the IT specialists are. Thus, requirements for the quality of their training are increasing each year. The dynamics of IT development in real world is extremely rapid that requires a permanent updating and actualization the content of the computer education (especially in academic training). It explains the training complexity for "Computer Science" specialists at all levels of higher education in Ukraine, and especially in the first (bachelor) level.

Numerous scientific papers highlight an educational content, problems which lead to the imperfections in the organization of the educational process, as well as they emphasize the need to diversify the forms of study. That is why, it is important to find the most effective model of professional training of a specialist adopted to its constant self-development and self-improvement, as it will ensure a high demand for such specialist in the labor market.

To improve the quality of the professional bachelors training in the field of computer sciences, it is necessary to determine (a) needs to be changed; (b) problems to be solved and (c) situation with demand for IT specialists to be predicted in the labor market. Therefore, our *aim* is to analyze the process of professional training of bachelors in computer sciences in higher education institutions of Ukraine and to identify its features. The *main tasks of our research* are (1) to analyze and to compare curricula and syllabuses of "Computer Engineering" and "Software Engineering" specialties in the main Ukrainian universities; (2) to find out features of above-mentioned syllabuses; (3) to reveal quantitative and qualitative indicators of these discrepancies in the curricula.

**Results:** The modernization of higher education in Ukraine has started with the development of new State Higher Education Standards (hereinafter *SHES*) for all educational levels after the adoption of the Law "On Higher Education" (2014). To date, the State Standards for Higher Education for specialties 123 "Computer Engineering" and 121 "Software Engineering" (knowledge sector 12 "Information Technologies") for the first (bachelor) level are accepted (Ministry of Education and Science of Ukraine, 2014). Currently, *SHES* for specialty 122 "Computer Science" is under development. Thus, the professional bachelors training of this specialty takes place based on standards, which were developed and approved during 2009-2011 for IT bachelors training. In spite of the need for the updating, these standards "correspond to international recommendations and programs of academic mobility of students in IT field and curricula of leading European universities" (Kovaliuk,

2011, p. 294). Bachelor's degree is obtained by students on the basis of educational programs developed by the higher educational institutions, approved by norms of the Law of Ukraine "On Higher Education" and recommendations of the Ministry of Education and Science of Ukraine. However, it should be noted that *SHES* is not a dogma. It defines the key competencies to be developed, but the higher educational institutions decide by their own on the development of relevant educational programs.

It should be emphasized that both bachelors and masters training in computer science in Ukraine takes place in areas that correspond to the directions defined in the Computing Curricula (CC 2001, CC 2005), the Computer Science Curriculum 2013 (CS 2013), Computer Engineering Curriculum 2016 (CE 2016), Information Technology Curriculum 2017 (IT 2017). One of the five areas identified by the mentioned documents is Computer Science, which is offered in the Ukrainian education system under the cipher 122 (ciphered 6.050101).

Our analysis of the features of the bachelors professional training in the field of computer science is based on the adopted *SHES* in the field 12 "Information Technologies", as well as current educational programs of National University of Kyiv-Mohyla Academy (hereinafter NUKMA) (Educational program "Computer Science", 2017) and profiles of educational programs 122 "Computer science" of leading Ukrainian universities offering training in this specialty, their curricula, as well as the information from Official websites of these universities.

The bachelors training in the field of computer science takes place in the higher educational institutions of Ukraine, mainly at universities (colleges train junior specialists; college graduates can continue their study at universities, they are enrolled on a general basis through competitive selection) based on educational programs compiled by the educational institutions. Therefore, curricula, educational programs and an offer of specialties (and its specializations) differ in different universities in Ukraine. To analyze the issue, the educational programs of the leading Ukrainian universities have been chosen due to the high quality of their IT graduates (moreover, these universities have a great popularity among applicants), viz. National University "Lviv Polytechnic", National Technical University "Kharkiv Polytechnic Institute" and National University "Kyiv-Mohyla Academy".

The National University "Lviv Polytechnic" in the profile of the program 6.050101 "Computer Science" emphasizes that this area combines the methodology and achievements of physical, mathematical and applied sciences and defines the object of the future bachelor's activity as a "projecting information systems, networks and computer programs; IT tools for them; computer simulation of control systems; computer systems projecting; computer intelligence decision-making systems". This program for bachelor's training includes a wide range of both fundamental and applied disciplines (physics, mathematics, computer science, natural and humanitarian disciplines).

The total volume of the bachelor's educational program is 240 credits ECTS, regardless of the specialty in Ukraine. Traditionally, 24 credits of study are dedicated to the social and humanitarian disciplines; the rest are dedicated to the fundamental, natural sciences and general economic training, as well as professional and practical

training. This ratio is maintained at the National University "Lviv Polytechnic" (i.e. 60 vs 156 credits respectively). Key learning outcomes are presented in three blocks: (1) general knowledge, skills and abilities; (2) domain knowledge and cognitive skills and (3) subject-specific skills. The general scientific competences of the first block include basic ideas about the foundations of philosophy, psychology and pedagogy; they are aimed at the development of a common culture and individuals' socialization under changing socioeconomic and sociopolitical conditions, and at an aesthetic formation; here is knowledge of history, economics and law, understanding of the causal relationships of the social development and the ability to use it in their professional activities.

The professional competence of the general scientific unit involves the use of existing knowledge in the subject in professional activity. It includes (a) fundamental knowledge of math, computer science and IT, as well as their application into the chosen profession; (b) basic knowledge of methods and techniques in system analysis; (c) ability to solve mathematical, physical, technical and economic problems, as well as the capabilities of technical and software decision making for scientific, technical and other applied tasks. The abovementioned competencies do not limit the scope of professional activity, on contrary, they expand a range of possible knowledge applicability.

Knowledge in the subject field correlates with the basic disciplines for bachelor's degree programs in computer science. They include (a) methodology for the development and application of informational computer systems, analytical and managerial techniques and tools for creating and maintaining these systems; (b) generalized and specialized programming languages; (c) basic principles and algorithms of information processing, modern IT, algorithms theory and math logic; (d) modern math modeling; (e) basics of the optimal control theory; (f) understanding of the modern computing systems' architecture, information and computer networks; (g) application management of databases and information systems; (h) methods and tools for data operations, methods of mathematical, logical and semantic, object and simulation modeling, technologies of system, cluster and factor analysis (National University "Lviv Polytechnic", 2017). Based on the acquired knowledge, graduates can develop the ability to conduct computational experiments using modern IT; to apply the optimization methods for mathematical programming solutions, decision making for organizational systems; to project, to implement, to test, to maintain software in computer systems and networks.

This block is aimed at acquiring the basic professional knowledge that will lead to an effective professional work in the future. These competencies outline the range of professional functions that bachelors in computer sciences can gain according to their qualification. The block of cognitive, subject and specific skills includes a variety of competencies. But its main goal is to provide further straightening of professional knowledge and skills based on the key abilities to self-development and self-improvement. They are (a) ability to learn new techniques, advanced technologies and innovations; (b) ability to use specialized knowledge and skills in basic disciplines in the analysis and creation of computer, communication, information

and other technical systems; (c) ability to apply knowledge and to solve qualitative and quantitative tasks; (d) ability to develop and apply methods of mathematics, informatics and IT system for problems solution in the theoretical and applied scientific researches, as well as in industry, engineering, economics, management, infrastructure organization etc; (e) ability to create computer systems with integrated information, to develop informational and system analysis techniques in accordance with the modern engineering concepts, information modeling to ensure the effective organizational structures' functioning; (f) computer information support skills for all kinds of work with integrated information (viz. information analysis, accumulation, image and application of knowledge, search for regularities and trends, modeling of information systems and processes); (g) ability to use methods and techniques for projecting, applying and supporting software analysis and decision making, their lifecycle, including expert and multi-agent systems, database and knowledge management systems, data and knowledge processing languages, ontology systems, computer and networks information.

Obviously, this block encompasses the broad professional context and open up new perspectives. This is important concerning with the IT development dynamics and the speed at which acquired knowledge loses its relevance in scientific and technological progress. It is essential that future graduates in computer science receive intensive language training. Such wide educational content is reasonable, since graduates have the opportunity to use their skills in different organizations, e.g. scientific organizations, IT companies, educational institutions etc.

NUKMA offers education by specialty 122 "Computer Science". Its educational program consists of 156 credits of the normative part, 144 of which are dedicated to the academic disciplines, 6 to workshops, 6 to the certification. The part of selective disciplines of the professional and practical training cycle is 59 credits; the students' choice for subjects is 25 credits. The total curriculum is 240 ECTS credits. The profile of the NUKMA educational program states that "specialists in computer sciences and computer technology can work in entities of all forms of ownership, of different profile and level, e.g. project organizations, consulting centers, scientific and educational institutions. They can solve issues, such as a development and implement complex computer systems, management of information systems and processes; organization of information systems; organization the search and information processing" (NUKMA, 2017).

Key learning outcomes consist of the following areas: (a) domain knowledge, (b) cognitive skills and subject-specific skills, (c) practical skills in the subject area, (d) general skills and abilities.

The first block covers a wide range of disciplines, viz. math analysis, functional analysis, computer algebra, data analysis, numerical methods, optimization methods, management theory, system analysis and decision making theory, programming, computer software, system programming, computer networks, information systems and databases, probability theory and math statistics, information coding theory, computational geometry, cryptology. Knowledge in the subject area is the basis for the formation and development of cognitive skills of future bachelors in computer

sciences that provide acquisition of (a) ability to use professional knowledge and practical skills in basic disciplines in the information processes; (b) ability to apply knowledge and skills to solve practical issues; (c) ability to use computer software products in the scientific work.

The educational program is aimed at practical skills gaining in the subject area within undergraduate program, i.e. (a) developing software products; (b) modern methods of effective access to information, its collection, systematization and usage; (c) methods of information identification and classification; (d) methods of modeling and forecasting, performing an output data evaluation; (e) developing mathematical models in the form of systems of differential equations, to use methods for solving differential equations; (f) building an effective computational algorithms to determine the program effectiveness; (g) rational algorithmization for solving optimization problems, as well as optimal control ones; (h) solutions of specific application tasks; (i) developing integrated information solutions for different entities; (j) applying modern methods of software complexes projecting; (k) collecting, processing, analyzing and systematizing the scientific and technical information by using advanced foreign and domestic experience in the computer software systems development [ibid].

The bachelors training involves the development of general skills and abilities that is a prerequisite for the further graduates' professional development. They consist of skills that provide general scientific development and those that are relevant to professional development. The general scientific development includes (a) ability to apply knowledge in practice; (b) ability to self-study and to continue professional development; (c) communication skills, including oral and written communication in Ukrainian, English and at least one of the most common European languages; (d) interaction skills, ability to work in team, learning conflict and stress management; (e) ability to self-organization and an efficient time management.

The professional skills development includes (a) ability to react to the external environmental factors by organizing of direct and indirect actions on the professional activity performance; (b) widening practical skills in computer data collection and processing; (c) ability to work with modern IT.

The *objects of the bachelor's degree* in the field of "Computer Science" are the development of algorithms, projecting, development and operation of computer software. The curriculum in this well-known educational institution includes a wide range of general scientific and humanitarian disciplines, e.g. history of Ukraine, history of Ukrainian culture, fundamentals of psychology and pedagogy, introduction to philosophy, fundamentals of law, fundamentals of economic theory, basics of entrepreneurship and business planning, political science. These subjects provide formation of outlook, legal, psychological, pedagogical and economic training.

Language training is implemented by studying the Ukrainian language in the field of professional orientation, English language, including professional English, and second foreign language, which is a distinguishing feature of bachelors' curriculum of this specialty at NUKMA. In addition, a military training course is mandatory. A distinctive feature is also the inclusion of the course of the Methodology of teaching mathematics and informatics in the curriculum of this university, which indicates a

fairly wide range of possible professional trajectories for graduates of the university. The professional component of the curriculum includes a wide range of subjects that cover both basic and traditional subjects and specialized disciplines. Attention is paid to the fact that unlike most universities, subjects of the general scientific and humanitarian block are not concentrated in the first year of the study, but 1-2 subjects are gradually included per semester throughout the entire period of study.

National Technical University "Kharkiv Polytechnic Institute" offers a specialty 122 "Computer Science" for bachelor level with different specializations. One of them is "Information and Analytical systems and technologies". The curriculum of the specialty (2017) contains general training courses, professional training, students' free choice disciplines, practice, final papers and certification, which amounts to 240 credits. The general training cycle is 71 credits and includes both disciplines of the general natural and scientific, general economic preparation of future bachelors, as well as special professional disciplines. 23 credits are devoted to general scientific disciplines, which are a traditional component of the content of higher education in Ukraine. They are history of Ukraine (3 credits), Ukrainian language (3 credits), foreign language (8 credits), philosophy (3 credits), history of Ukrainian culture (2 credits), fundamentals of economic theory (2 credits), ecology (2 credits). In addition, 12 credits are dedicated to the physical training, which is included in the curriculum in 1-6 semesters. The cycle of general training also includes a number of disciplines that are the basis for bachelors training, as well as many other specialties of technical direction. They are: physics (4), linear algebra (4), math analysis (9), discrete math (8), probability theory (4) and math statistics (4). General training subjects are distributed through semesters of the first and second years, except for two: ecology takes place in 6<sup>th</sup> semester, and economics and software products organization in 8<sup>th</sup>.

Professional bachelor's training takes place throughout the study and consists of disciplines of specialty and specialization; the cycle of professional training equals to 145 credits, of which 33 credits for professional training in specialty and 112 credits in specialization. Among the traditional subjects in computer science, the following are offered: history of science and technology (2) and fundamentals of occupational safety and health (3); within the framework of professional training – financial and managerial accounting (4) and fundamentals of logistics (4). The bachelors' curriculum also includes military training (19); practice (6), final papers (3) are mandatory. The course is completed by defending a final project.

A curricula analysis of the three leading higher educational institutions in Ukraine, where the bachelors training in computer science is carried out, showed significant differences (by the number of disciplines, their content and semesters of their study). Certain mismatch can be explained by specializations that can have a significant effect on the formation of the training content. In addition, it is obvious that both a status of the higher educational institution and its profile (academic or technical) determines the subjects proposed for studying and their scope. Only 10 disciplines of vocational training coincide with those selected for analysis in higher education institutions, the rest vary or even have a tangible relation to disciplines in the list of other universities. It is clear that despite different disciplines, most of them have

intersection and essential focus on various aspects of the specialty. However, such diversity in the training content is evidence of the lack of a coherent vision of the content of the basic bachelors training in computer science.

The largest range of subjects for both general and professional training is offered by NUKMA. In the general training block, the attention is paid to the expanded language training, which includes Ukrainian language for professional orientation, practical English, professional English and correction course, which seems sufficient to reach B2 level, as well as the course of the second foreign language. Above-mentioned creates additional preferences for NUKMA's graduates including chances for students to participate in various educational projects, mobility programs, etc.

The subjects 'history of Ukraine' and 'history of Ukrainian culture' are traditional in the state system of higher education in Ukraine. These disciplines are presented in the content of general training in all institutions in Ukraine. However, it should be noted that 'history of Ukraine' is one of the school curriculum subject, which is included in the list of obligatory subjects of the state scholars' certification. The certificate on 'history of Ukraine' is one of three, which is submitted to the admission committee. Therefore, inclusion of this subject in a higher institution curriculum is a kind of "review section", which is unreasonable, in our opinion.

Other training courses included in the general training cycle in the curricula, are 'foundations of economic theory and economics', 'enterprise organization' and 'philosophy'. These subjects do not fit the curricula; however, they are part of educational content in all of three universities. There are significant differences; e.g. 'ecology' and 'jurisprudence' (aka 'fundamentals of law' in NUKMA), 'political science' and 'psychology' (aka 'fundamentals of psychology and pedagogy' in NUKMA) are proposed by "Lviv Polytechnic" and NUKMA, while National Technical University "Kharkiv Polytechnic Institute" does not offer such subjects. In addition, the curriculum of "Lviv Polytechnic" includes sociology, management and life safety, and the list of disciplines for bachelors in computer science in NUKMA includes 'foundations of Internet business'. "Lviv Polytechnic" supports the law making component of the bachelor's degree in computer science with another discipline offering the course 'legal support of professional activities', which is a justified step taking into account features of IT sphere.

It is obvious that the subjects' proposal of the general training cycle is formed taking into account students' needs and requests, but on the other hand, the presence of qualified scientific and pedagogical staff who can provide teaching on the offered educational disciplines is essential. The trend of bachelors' training to the practice, as in the case of National Technical University "Kharkiv Polytechnic Institute" has a key priority. By the way, the focus on the practical needs of graduates is inherent in most technical universities, therefore, general training is usually limited to 4-5 disciplines including 'history of Ukraine', 'history of Ukrainian culture', 'philosophy', 'foreign language' and 'Ukrainian language for professional activity'. Professional training reveals even more discrepancies. Common disciplines in the cycle of all universities are discrete math; 'fundamentals of discrete math', 'algorithms and data structures', 'computer architecture' / 'computing systems', 'probability theory' and

'math statistics', 'math methods of operations research', 'computer / information / intelligent networks / intelligent information systems'. The rest of the curriculum are different, but mostly because of the fact that last two years the consolidation tendency for disciplines has significantly increased.

**Conclusions:** Within the framework of the "Computer Science" training, universities offer a variety of specializations (especially technical universities and institutes), which significantly affects the choice of priority disciplines of professional training. In general, the content of the bachelors professional training in computer science corresponds to the general educational tendencies in European and world practice, since SHES and educational programs development rely on the Computing Curricula (2001-2005) and aimed at acquiring higher education students of the first (bachelor) level of those professional skills that are integral for IT specialists and ensure the ability to perform professional tasks. However, the training content although it has a common core, is still not identical in different institutions of higher education. The universal component in educational content reveals discrepancies, both in terms of the proposed disciplines and in terms of the number of credits for their study.

The discrepancies in the quantitative and qualitative indicators of the curricula can be explained by the status of a higher education institution, its orientation to the professional training to a wide range of specialist training or a thorough preparation within the subject area of 122, as well as specializations that significantly affect the formation of education content. Sometimes the list of curriculum disciplines depends on the availability of scientific and pedagogical staff capable to provide training.

## REFERENCES

- Computer Science Curricula (2013). Available at: [https://www.acm.org/binaries/content/assets/education/cs2013\\_web\\_final.pdf](https://www.acm.org/binaries/content/assets/education/cs2013_web_final.pdf).
- Basic Principles for the development of an Information-Oriented Society in Ukraine for 2007-2015 (2017). Available at: <https://zakon.rada.gov.ua/laws/show/537-16>.
- Kovaliuk, T., & Efimenko, O. (2011). On the development of IT education in Ukraine. Available at: [http://ena.lp.edu.ua/bitstream/ntb/12575/1/049\\_Kovaljuk\\_293\\_297\\_719.pdf](http://ena.lp.edu.ua/bitstream/ntb/12575/1/049_Kovaljuk_293_297_719.pdf).
- Official website of the Ministry of Education and Science of Ukraine (2019). Available at: <https://mon.gov.ua/ua>.
- Educational program "Computer Science" (2018): National University "Kyiv-Mohyla Academy". Available at: <https://www.ukma.edu.ua/ects/index.php/2011-04-18-08-31-28/181-bakalavr/bpi/275-2018-11-16-11-00-22>.
- Official site of the National University "Lviv Polytechnic" (2017). Available at: <http://edu.lp.edu.ua/napryamy/6050101-kompyuterni-nauky>.
- ECTS Information Package: National University of Kyiv-Mohyla Academy (2017). Available at: <http://www.ukma.edu.ua/ects/index.php/2011-04-18-08-31-28/181-bpi>.
- Educational programs of NTU "Kiev Polytechnic Institute" (2017). Available at: <http://vstup.kpi.kharkov.ua/osvitni-prohramy>.