



TRAINING OF PRE-SERVICE TEACHERS OF COMPUTER SCIENCE IN COMPUTER GRAPHICS

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Abstract: *The article is devoted to the issue of teaching computer graphics to students of computer science at pedagogical universities, which is related to the development of information and communication technologies and modern trends in education. Based on a survey conducted with the participation of the authors of more than 250 representatives of IT companies and computer science teachers, it has been determined what life competences should be formed by teachers in students within computer science classes according to the requirements of the labour market, which sections of computer graphics are promising for student learning and therefore important for training of pre-service teachers of computer science.*

The content of computer graphics training for pre-service teachers of computer science at five pedagogical universities of Ukraine is analysed, the system of computer graphics training for pre-service teachers of computer science at the National Pedagogical Dragomanov University is described. Besides, the structure is presented and the need for the introduction of a specially developed electronic training course for distance learning of pre-service teachers of computer science is defined. It is determined which components of the information and digital competence of pre-service teachers of computer science the course in computer graphics should be aimed at. It is noted that this course contributes to the formation of important information-digital and professional competences, which are necessary for a modern specialist in the field of computer graphics as well as for a pre-service computer science teacher. The teachers who took part in the survey emphasised that they lacked qualification in dealing with such methodological issues as active methods of teaching computer science (51.1%), the cognitive-research method (44.8%), the educational project method (41.6%) etc.

Keywords: computer graphics, preparation of pre-service teachers of computer science, competence approach, digital competences.

INTRODUCTION

The globalization processes taking place around the world, technological and demographic changes, as well as digital transformation, are increasing the demand for high-level skills of graduates and, at the same time, require new, broader skill sets that will contribute to the digital transformation of the economy in society on the one hand and, on the other another, expand digital, entrepreneurial and other skills of the 21st century.

There is an ongoing modernisation of education in Ukraine. A key reform of Ukrainian education is related to the concept of the New Ukrainian School. To this end, work is constantly being carried at the legislative level and through practical, psychological and methodological assistance to teachers who work in the conditions of the implementation of this Concept.

In line with the changes taking place in today's digital society, the standards of education are changing in different countries, and the content and importance of some educational subjects are often changing. This is particularly true for the subject of computer science (Webb, Davis, & Bell, 2017).

Digital competence is becoming a basic competence and a component of 21st century literacy not only for pupils and students, but for every citizen, because the digital society technologies permeate all fields of human activity.

The ICILS 2018 International Survey of Computer and Information Literacy concludes that young people do not acquire developed digital skills through the simple use of digital devices. Simply providing students or teachers with equipment is also not sufficient to develop their digital competences (IEA Releases, 2018).

Many EU Member States are reviewing educational standards and integrating digital literacy into primary school, as well as new components such as artificial intelligence, digital citizenship and computer science (Digital Education Plan 2021–2027) In particular, this EU action plan indicates the need to increase digital skills and competences, which requires:

- Development of basic digital skills and competences from an early age;
- Digital literacy, including anti-disinformation measures;
- Digital education;
- In-depth knowledge and understanding of data-intensive technologies such as artificial intelligence (AI);
- Advanced digital skills to train more digital professionals;
- Ensuring equal representation of girls and young women in research and digital careers.

Educational standards are also changing in Ukraine. A new strategy for studying computer science is being discussed. The State Standards of Primary and Secondary Education (2018, 2020) define the following 4 learning outcomes for computer science:

1. Searching, presentation, transformation, analysis, generalization & systematisation of data, and critical evaluation of information to solve life problems.
2. Creation of information products and programmes to effectively solve tasks/problems effectively, creative self-expression (individually and in cooperation) with and without the help of digital devices.

3. To use of information & communication technologies and digital devices consciously to access information, communicate and cooperate as a creator and/or a consumer.
4. Awareness of the effects of the use of information technologies for oneself, society, the environment and sustainable development of society, compliance with ethical and legal norms of information interaction.

Research goal. The article examines the results of a study on determining the level of readiness of Ukrainian educators to use computer graphics tools. It attempts to answer the following questions:

- analysis of the theoretical basis of the research;
- analysis of digital competence of modern computer science teachers;
- analysis of the level of readiness of Ukrainian educators (target group) to use computer graphics tools based on the survey data.

Hypothesis: taking into account the rapid development of digital technologies, the authors believe that the efficiency of education in general will increase by raising the level of their Digital Competences, especially skills in using computer graphic tools.

Research methods. The authors used the following research methods and tools in the study:

- survey;
- interview with Ukrainian educators;
- document and content analysis;
- analysis of research papers.

The present study involved 221 Ukrainian educators and 16 heads of IT companies.

1. THE THEORETICAL BACKGROUND OF THE RESEARCH

In order to determine the opinions of IT specialists and computer science teachers on the status and updating of the goals and content of computer science education, in accordance with new educational standards, 16 heads of IT companies and 221 teachers of computer science were interviewed as part of the “Computer Science – New Generation” project. They noted that the school computer science course should form soft skills, which are very important in life and work (Table 1, Figure 1, Figure 2):

Table 1.

Skills	Opinion of IT specialists	Opinion of Computer Science Teachers
Critical thinking	93.8%	82.4%
Ability to work with data and information (search, analysis, transformation, generalization, systematization and submission of data)	75%	84.6%
Problem solving	100%	53.8%
Communication, collaboration and teamwork	87.5%	63.8%
Self-mastery of new technologies	43.8%	64.3%

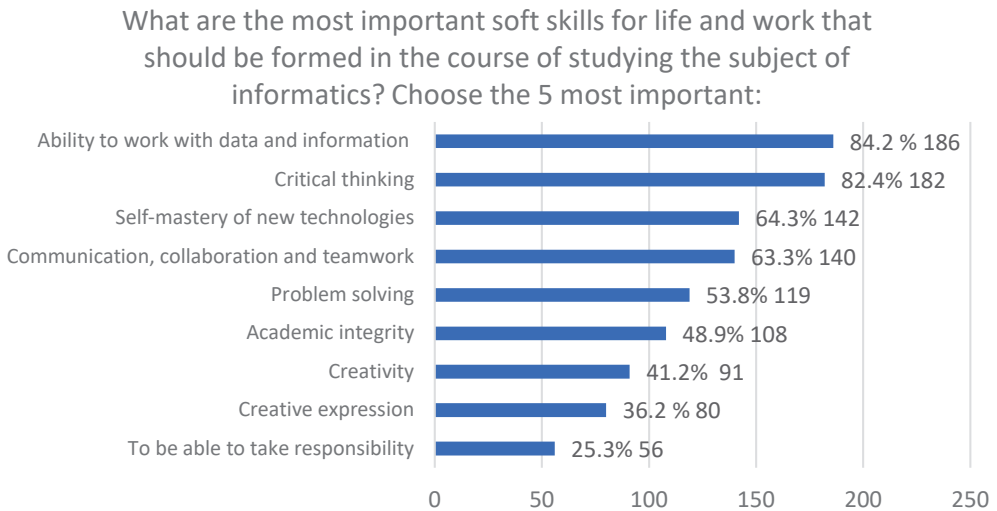


Figure 1. Teachers' answers

Source: Own work.

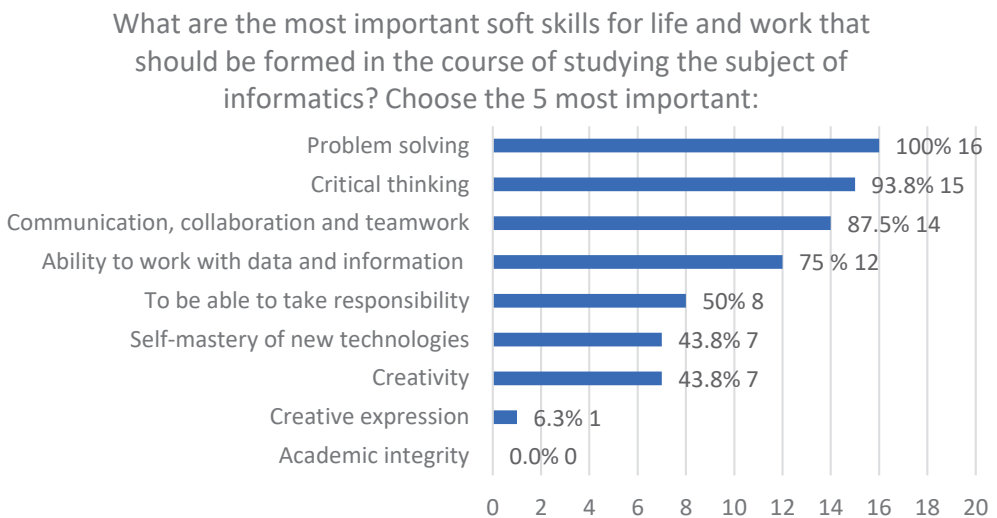


Figure 2. IT specialist's answers

Source: Own work.

The analysis of the answers of the respondents shows that significant changes should be made not only in the content, but also in the methods of training pre-service teachers of computer science in order to meet the needs of the labour market regarding the skills and competencies of graduates of secondary education institutions. Apart from information and digital competence formed at a sufficient level, pre-service teachers must have key competences necessary for successful self-realization and lifelong learning, which requires the content of the subject of computer science. It is required by the content of the subject of computer science. The content is constantly and rap-

idly changing due to the corresponding changes in digital technologies. The information and digital competence of the re-service computer science teachers includes:

- A3.1. Ability to navigate in the information space, search and critically evaluate information and to use this information in professional activities.
- A3.2. Ability to effectively use existing electronic (digital) educational resources new ones, if necessary.
- A3.3. Ability to use digital technologies in the educational process (Standard for the professions, 2020).

Digital literacy is one of the key competences of future teaching staff. The discussion on digital literacy and how it is measured is part of the reflection on the shape of the future school and educational programmes at pedagogical universities. Understanding the state of *preparation* of new pedagogical cohorts in the intensively developing information society requires the organization of those conclusions reached so far by relevant research. For this purpose, a systematic analysis of the literature (peer-reviewed articles) indexed in repositories and scientific databases such as Google Scholar, EBSCO, Scopus and Web of Science was used. Based on data from 2001 to 2021 on Polish students, these being future educators, it was noted that:

1. Measurement of digital literacy is rare, theoretical analyses are preferred.
2. The research is dominated by quantitative techniques and tools mostly deprived of theoretical framework and psychometric properties based on a number of inconsistent indicators.
3. Occasionally DigCompEdu, TPACK, Eurostat typologies are used for measurement.
4. Digital literacy measurement is mostly based on students' self-declarations.
5. Surveys are conducted in different centres without representative samples, and the samples used are usually small.
6. The level of digital literacy is most often described as average or good.
7. Students of pedagogical faculties prefer to rely on common software and services of the information society.
8. Attitudes towards new media in education vary within this group.
9. There is a need to develop new, standardized research tools measuring digital literacy, which might nullify the Dunning–Kruger effect. (Tomczyk, 2022).

When training pre-service teachers, the pedagogical university must focus on the challenges of the times and change the educational programmes for the training of specialists in accordance with the current legislation of Ukraine. Therefore, educational programmes for teacher training are constantly analysed, modernised and improved. Computer science teachers are trained according to the educational programme of training in the specialty 014.09 Secondary education (Computer Science), the curriculum of which was updated in 2021. Graduates receive the qualification “Bachelor of Education (Computer Science)”, teacher of computer science in a general secondary school.

The purpose of the computer science course is to develop the personality of a student who is able to use digital tools and technologies to solve problems, develop, creatively express themselves, ensure their own and social wellbeing, think critically, act safely and responsibly in the information society.

This means that the university must train a specialist who possesses these competences and will be able to teach them to his/her students as well.

One of the important modules that respondents pay attention to is working with graphic objects (Table 2 and Figure 3). Thus, 221 teachers rated the importance of blocks related to computer graphics according to the needs of the labour market in the following way:

Table 2.

The name of the block related to the graphics	0 not important at all	1 partially important	2 not very important	3 important	4 very important
Processing of multimedia objects	0	11	38	66	106
Computer Graphics	0	6	48	94	73
Computer animation	3	19	53	90	56
3D-graphics	0	18	58	90	54

Source: Own work.

Related to computer graphics according to the needs of the labor market in the following way on a scale from 0 to 4, where 0 is not important at all, 4 is very important

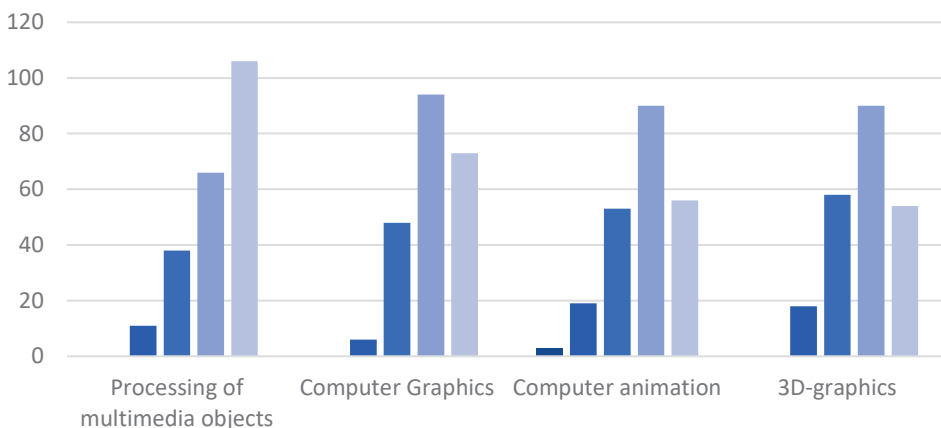


Figure 3. Distribution of answers regarding blocks of the computer science course by importance of priority according to market needs

Source: Own work.

That is why the purpose of the article is to analyze issues related to the training on computer graphics for pre-service teachers of computer science in accordance with the new conditions of the labor market and taking into account the skills of graduates of secondary education institutions, and determination of ways to modernize the system of the training.

Computer graphics and design includes the technology of creating and processing graphic images with aesthetic and functional properties, using computer equipment. A graphic designer works on the visual appeal of a product when creating a website, logo, company brand or print design. Specialists in the field of Graphic Design are constantly learning new design methods, software technologies and work methods. This field is dynamically developing and is in high demand both in the service and private employment markets. The US Bureau of Labor Statistics predicts that graphic designers will have 35% more online design job opportunities by 2026. At the same time, traditional print publishers and mass media will cut the number of designers in the printing industry by 22% (US Bureau, 2021).

Among all creative specialties, it is difficult to find a more popular one than graphic design. Such a specialty as “Graphics and multimedia in IT”, for example, is currently one of the most popular in all countries.

Computer graphics and computer design is one of the content-determining disciplines that should form an individual’s modern digital competence, which is included in the list of key competences and cross-cutting skills in accordance with the State Educational Standards of Ukraine and which is emphasised in the Recommendations of the European Parliament and the Council of the European Union on the formation of key competences of lifelong education. This competence allows one to organically exist in society at the level of a developer of computer products or their user.

Computer-aided design is the main means of visual communication. When training pre-service teachers, they (teachers) must develop basic digital competences for working with graphic data:

- ability to use specialized effects for animation processing and video design;
- ability to use digital technologies to process graphic images, animations and videos;
- ability to find, process, analyse and evaluate information related to professional activity;
- ability to use existing computer technologies to solve the problems of planning the educational process;
- ability to use specialised software and modern means of information storing and processing;
- ability to choose and use computer technologies to solve various pedagogical problems;
- ability to create simple computer pedagogical software tools to introduce new computer technologies into the educational process;
- ability to create and edit vector graphic images of varying complexity.

The State Standard provides basic knowledge that can be attributed to computer design issues. Issues of computer graphics are most closely related to design: raster and vector images, their objects and properties; construction and processing of graphic

images in various software environments; three-dimensional graphics; animation; concepts of 3D modelling programs and 3D printing.

The study of the topic “Computer presentations” is closely related to computer graphics: visualization of messages, computer presentations, their objects and properties; stages of creating a presentation and requirements for its design; presentation objects and means of managing its demonstration; animation effects, movement of objects in presentations; planning a presentation and speaking in front of an audience.

In the process of studying the topic of “Web resources”, automated means of creating and publishing web resources are considered; the language of hypertext markup and ergonomic placement of information on the web page should be also considered. As regards the topic of “Multimedia”, it covers the problems of processing multimedia objects, construction of audio and video sequence and publishing multimedia (State standard of basic secondary education, 2020).

2. ANALYSIS OF TEACHING COMPUTER GRAPHICS DISCIPLINES IN PEDAGOGICAL UNIVERSITIES OF UKRAINE

All these questions are considered in a computer science course in primary school and may be of interest to those who wish to build their future careers in the field of computer graphic design.

The analysis of research and publications shows that the pedagogical literature considers methodological issues related to the teaching of computer graphics concepts to students (Horobets, 2014), methodological principles of teaching are investigated by Hevko (Hevko, 2017) and others. Some studies consider the training of a specialist in computer graphics just from the standpoint of the formation of appropriate graphic and design competences (Cherniakova, 2010) but methodological approaches to teaching computer graphics to pre-service computer science teachers are not sufficiently covered in the literature.

Pedagogical universities provide education according to educational programmes in which issues of computer graphics and computer design are included. Some study programmes combine computer graphic design with other fields such as interactive media. In the course of the research, the curricula of pedagogical universities of Ukraine were analysed in order to determine which branches of computer graphics disciplines are studied during the training of specialists. As it turned out, these disciplines are included in the bachelor degree educational programmes 014.09 Secondary education (Computer Science).

The Volodymyr Vynnychenko Central Ukrainian State Pedagogical University trains such specialists at the Faculty of Mathematics, Natural Sciences and Technologies. The discipline “Computer graphics” (3.5 credits) is included in the block of bachelor degree professional training 014.09 Secondary education (Computer Science) with a specialisation “Secondary education” (Computer Science and Mathematics). The Faculty also offers a related discipline “Professional work with graphic packages” in the university-wide list of elective disciplines.

Ternopil's Volodymyr Hnatiuk National Pedagogical University (to be precise, its Faculty of Physics and Mathematics) offers the discipline of "Computer Graphics". This discipline is in the elective block 014.09 Secondary Education (Computer Science); the second subject specialisation is 014.04 Secondary Education (Mathematics) of the educational programme 014 Secondary Education.

The South Ukrainian K. D. Ushynsky National Pedagogical University (to be precise, its Faculty of Physics and Mathematics, Department of Applied Mathematics and Computer Science) offers bachelor degree studies in Computer Science. "Computer design" is included in the list of disciplines of the bachelor degree professional training block. "Computer graphics" is also among the disciplines of this department.

For 2022, Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University offers "Digital technologies for processing graphic images, animation and video". It is in the list of elective educational disciplines for full-time and part-time forms of bachelor degree studies. The course covers raster, vector and 3D graphics editors.

The National Pedagogical Dragomanov University (Faculty of Mathematics, Computer Science and Physics) plans to start the course "Fundamentals of Computer Design". It is part of the bachelor degree educational and professional training programme in the specialty 014.09 Secondary Education (Computer Science). According to the curriculum, which was updated and approved in 2021, 90 study hours are planned for the study of the discipline, of which 34 hours are taught (16 hours – lectures, 18 hours – laboratory work) and 56 hours – students' independent work. The course plans to study topics that will be propaedeutic for the disciplines "Fundamentals of web technologies and web design" and "Fundamentals of 3D technologies", which are offered to students in the 1st and 2nd courses of training. Students of the 3rd year have the opportunity to choose the specialization of "Computer design" and can continue to study computer design issues in the courses "Web technologies and web programming", "Computer graphics and animation", "Virtual and augmented systems reality", "Multimedia systems and technologies", "Methodology of teaching computer design", and "3D technologies and 3D modelling".

Students gain technical skills using many different types of technology, including graphic design software, sound devices, cameras and printers. They also gain additional skills such as attention to detail, analytical skills and creativity. A very important experience is when students have the opportunity to create their own portfolio to demonstrate their abilities to potential employers. This could be, for example, coursework (course paper) that would include graphic design, typography, web design, advertising design, digital photography, and interactive design techniques. This can prepare students for careers in a variety of fields including animation, visual marketing, advertising, logos, and visual media.

3. WAYS OF IMPROVING DIGITAL COMPETENCES OF UKRAINIAN EDUCATORS

Respondents emphasized that teachers need the following types of educational resources for quality teaching, (Figure 4), which indicates that when training pre-service teachers, they should be taught not only to create resources, but also to use them effectively.

These include electronic platforms (72.4%), environments for the development of critical thinking (71%), examples of programs with some errors (they need to be found and fixed (63.8%), screen casts (57.5%), video files from practitioners (54.8%), etc.).

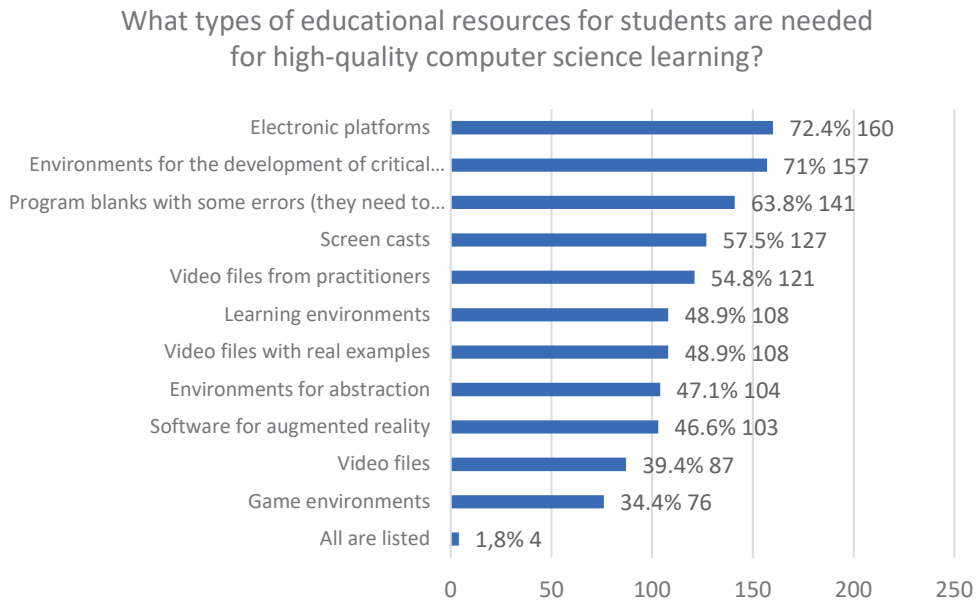


Figure 4. Types of educational resources for high-quality education of students

Source: Own work.

At the same time, almost 100% of the interviewed teachers indicated a lack of competence tasks. Therefore, it is advisable to use competence tasks when choosing the tasks of the course “Fundamentals of Computer Design”. The technological functions of computer graphics are considered as tools for solving project tasks used in print advertising, business presentations, casual games, identity development, 3D modelling and the creation of animated plots/stories. To master computer graphics tools, students are offered to complete projects that they could face in real life:

- creating the identity of your own software development company, design bureau, group by interests (fans of fantastic fictions, cakes, music, etc.);
- organization of a public event: alumni meeting, computer science olympiad, science week.

In order to prepare projects, it is necessary to create instructions, which describe the requirements for the portfolio to be prepared. Students are encouraged to form groups of 2–3 people, but due to the fact that classes have been held online for the last 3 years, this has become problematic. Students do not know each other very well, they have little time for personal communication, and such relationships have proved unproductive. Therefore, projects are mostly individual.

An electronic training course was created to train students in computer graphics using innovative pedagogical methods (<https://moodigital.literacye.fmif.npu.edu.ua/course/view.php?id=800>).

The course is structured thematically:

1. General information about design and computer graphics
2. Copyright of programs and images. Different types of licenses
3. Raster graphics
4. Vector graphics
5. Infographics and business graphics
6. Animation
7. 3D graphics and modelling
8. Web design, website image optimisation

Each topic contains theoretical material, tasks to be performed and test questions. The teachers who took part in the survey emphasised that they lacked consideration of such methodological issues in their qualification improvement (Figure 5): active methods of teaching computer science (51.1%), cognitive-research method (44.8%), the educational project method (41.6%), etc. This emphasises the relevance of the created electronic course for teaching computer graphics, in which the mentioned techniques are implemented.

Indicate the subjects of the courses most necessary for qualification improvement:

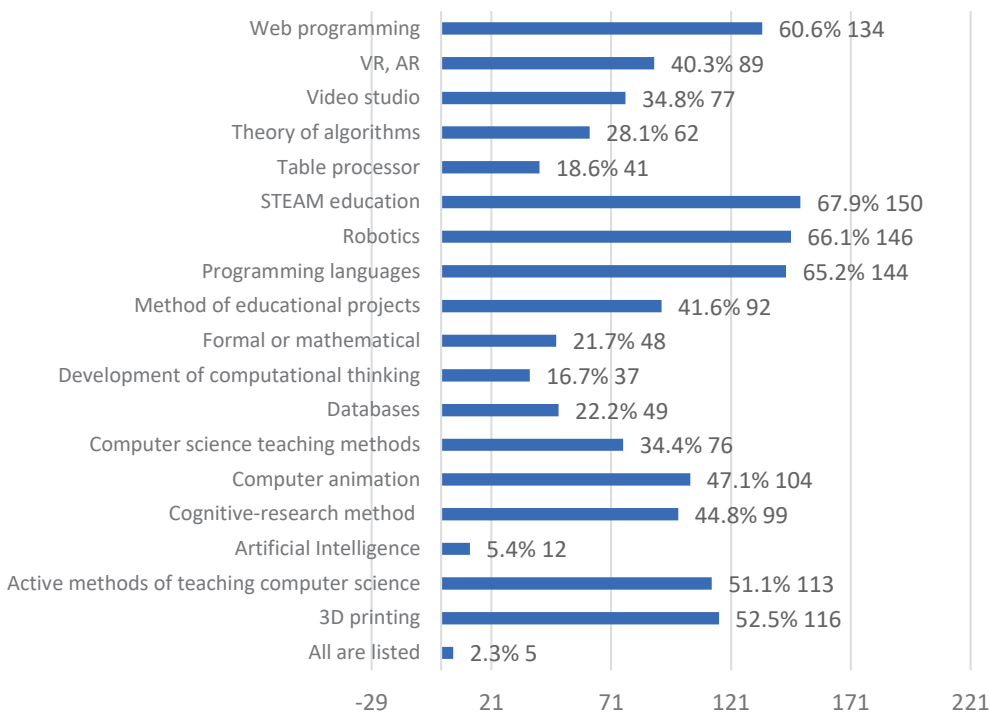


Figure 5. Distribution of answers regarding the subjects of the courses that are most necessary for improving the qualifications of computer science teachers

Source: Own work.

CONCLUSION

Pre-service teacher training should ensure the formation of key competences necessary for successful self-efficacy and lifelong learning. It is about general competences as well as information and digital competences. Only complete and comprehensive knowledge of the subject will help the teacher correctly answer the questions posed by the inquisitive mind of the pupil/student.

As practice shows, many teachers lack modern technologies and teaching methods. There are many reasons for this, but the most important one is that pedagogical universities train specialists who do not meet the needs of the current labour market. The higher education system of Ukraine in its activities is oriented to the population's demand for educational services without taking into account the requirements of the labour market. The Ukrainian education market and the labour market share common features, such as the lack of analysis and forecasting of the number and qualifications of workers needed by the economy, the lack of a flexible system for determining the qualifications of a specialist, as well as the weak connection between higher education institutions and potential employers. The current reality requires different competences from a specialist than 30 years ago. In 2022, Ukraine ranked 85th in the World Competitiveness Rankings. The main reason is the war in the country, but even before that in 2021, we Ukraine came only 54th. As the survey results show (Figure 2), employers want to see the kind of modern specialist who can solve problem situations independently (100%), has highly developed critical thinking (93%), is ready to communicate and cooperate (87.5%), knows how to work with data and programs (75%) and is creative and able to learn independently (43.8%).

Therefore, a pedagogical university should change the content and methods of teaching teachers and students in accordance with the needs of the labour market, and teachers should respond adequately to social orders, contribute to the formation of the creative personality of specialists in various branches of the national economy, and activate the educational and creative activities of students. For the effective assimilation of educational disciplines and the formation of creatively gifted pre-service teachers of computer science, professors and trainers need to build an educational process based on active learning methods using didactic laws, principles, methods and forms. One of the most promising ways of improving the training of pre-service specialists is the introduction of forms and methods of active learning. Active learning methods combine forms of individual and collective acquisition of professional knowledge, abilities and skills. The most effective of these are situational methods: seminars, discussions, practical classes, project activities.

There is a growing need in information, technological and visual literacy of school leavers and an understanding that students have changed and educational practices have not. This requires the presence of a significant number of teachers who have practical skills in the use of information and communication technologies, as defined by international educational communities and organisations.

Preparing pre-service teachers of computer science to use various teaching methods, demonstrating work output created with the help of graphic editors and tools for working with graphic resources will also contribute to increasing students' motiva-

tion to study, which, in turn, will contribute to the determination of the future profession and the formation of self-study skills.

“Universities will rely less and less upon their reputation of ‘centers of excellence’; universities will become laboratories / ateliers for developing youngsters’ talents through special design- and problem solving tasks, revealing real solutions for real problems. Master students will undertake assignments, experiments, designs and theses, compared to what PhD students achieve nowadays. PhD students will shift towards unique boundary-cutting research instead of performing research that has been prompted by the professor” (Kommers, Smyrnova-Trybulska, & Morze, 2018).

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