INFORMATION AND LEGAL FOUNDATIONS FOR THE PROFESSIONAL TRAINING OF AVIATION SPECIALISTS

Monograph

Katowice 2022

Information and legal foundations for the professional training of aviation specialists

Edited by Oksana Danylko and
Magdalena Wierzbik-Strońska

Series of monographs
Faculty of Architecture,
Civil Engineering and Applied Arts
University of Technology, Katowice
Monograph 55

Publishing House of University of Technology, Katowice, 2022

Series of monographs Faculty of Architecture, Civil Engineering and Applied Arts, University of Technology, Katowice

Monograph · 55

ISBN 978-83-963977-8-2
DOI: 10.54264/M010

Editorial compilation
Publishing House of University of Technology, Katowice
43 Rolna str. 43 40-555 Katowice, Poland
tel. 32 202 50 34, fax: 32 252 28 75

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VIRTUAL LABORATORIES AND 3D PRINTING TECHNOLOGIES FOR THE IMPLEMENTATION OF STUDENTS' RESEARCH PROJECTS IN AVIATION

The society is creating new challenges as for the requirements for Air Transport students' training . They include an idea of what a professional should be like and define his or her purpose and role in society. This requires new methods, techniques and technologies: methods of experimental and theoretical study of objects and processes in air transport, which determine the subject area of one's education, and determine what to expect from education and society. Professional education is increasingly focused on "free development", high culture, creative initiative, independence, mobility of future professionals, which requires a qualitatively new approach to forming future aviation professionals. The purpose of modern higher education in speciality "Aviation Transport" is to train a competent specialist who is ready to solve practical problems of air transport in the area of aviation robotic systems. In addition, future professionals must constantly work on professional growth, be socially and professionally mobile, able to effectively use information resources in future activities and when acquiring professional education. Modern information technologies encourage future specialists in the field of "Air Transport" for self-improvement, but the introduction of information technology in the educational process does not always take into account the specifics of specialties for which computer science is not a professional subject. This creates new challenges for the future aviation specialist training. The study of the problems of informatization of higher education for future specialists in the field of "Aviation Transport" and the introduction of information technology in the educational process is given little attention in scientific papers. The study of theoretical and practical aspects of the problem of developing the professional competence of aviation specialists has become a new subject of scientific interest. Problems of computer-oriented methodological systems of education in universities were studied by O. Honcharova, Yu. Lotiuk, V. Klochko, Ye. Smirnova-Trybulska etc.

Today requires personality-oriented learning, which determines the leading strategic direction of the education system, both general and professional. The main ideas of personality-oriented learning are determined by the maximum development of cognitive abilities, creative disclosure of the learner's personality. In particular, learning is a process of individual activity of the person receiving education. It is aimed at: acquiring and transforming socially significant patterns of actions and subjectivity of those who receive education[23].

Thanks to the computer-oriented educational environment, higher education can solve a number of general pedagogical and psychological tasks and tasks of forming and developing personality on a qualitatively different basis.

Let us consider the scientific and practical issues of constructing and using computer-based environment in the educational process.

There are two aspects to implementing the latest computer-based learning systems and tools. Sets of educational equipment in the educational process create additional opportunities for the use of the latest personality-oriented educational technologies. There are opportunities for differentiating the educational process, ensuring the fullest possible development of inclinations and abilities, meeting the necessary needs and requirements of the educational process, which reveals the creative potential of future professionals.

The second aspect of applying the latest computer-based systems and teaching aids concerns necessary life competencies. Sets of educational equipment as a means of educational activities develop the scientific and technological culture of future professionals. This is today an important component of the overall culture of each person and society as a whole[24]. The new generation of modern teaching aids has significantly contributed to the emergence of new computer technologies, such as "virtual laboratories" and "3D printing". In addition, today it is difficult

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[23] Науменко, О. М. (2011). Основні ознаки комп'ютерно орієнтованого освітнього середовища і шляхи його формування. Інформаційні технології і засоби навчання. Електронне наукове фахове видання 4 (24).

[24] Там само.

to imagine learning without the use of presentation tools, computer applications and integrated learning environments designed to help develop skills, evaluate learning outcomes, create research models and forms of education during which future professionals can learn and educate themselves. In fact, it can be noted that the system of modern teaching aids has formed specific subsystems of tools that are based on the use of computer-based learning tools[25].

Advances in the field of informatization of education, which provide for the use of potential opportunities of modern information technology not only in the management and organization of the learning process, but also in the communication of educational entities, contribute to the intensification of all levels of educational process. Opportunities are being implemented that increase its efficiency and quality. Future specialists are preparing for a comfortable life in the conditions of informatization of society, both psychologically and practically. Updating the content, forms and methods of teaching is due to the introduction of IT in the management and initial process of educational institutions. An integrated approach to the implementation of IT is determined by the concept of informatization of education[26], which provides that the management and initial process of educational institutions must meet the modern requirements of modern information society as a whole. Here are the concepts of technology that are associated with the informatization of education. Information technology is a set of methods and software and hardware implemented for the collection, processing, storage, dissemination, display and dissemination of information. The more general term Information Technologies, which is higher in the hierarchy, is also used, the term Information and Communication Technologies (ICT). Currently, the activities of each person have become highly dependent on the latest technologies, which contributes to their continued development. Information and communication technology implements a single form, system, common technology standards and integration of telecommunications (wireless connections), computers, software, visual systems that allow users to create, access, store, transmit and modify information. Thus, information and communication technologies are part of information technologies, as well as all types of telecommunications and media broadcasts. All types of audio and video processing, transmission, network management and monitoring functions are provided by modern information technologies. In the educational process, new information technologies determine the methodology and technology of the educational process using modern electronic means. The full functioning of the educational institution today, in the information society, is impossible to imagine without the introduction of information technology in the educational process. It is worth noting the pedagogical tasks they implement:

- improving the efficiency and quality of the educational process;
- intensification of all levels of the educational process;
- formation of an open education system;
- integration of subject areas of knowledge;
- development of creative potential;
- development of information competence.

Visualization of knowledge in aviation education.

Current trends in distance learning in the training of aviation professionals require greater use of information technology: the use of Internet space, the involvement of interactive technologies that contribute to the visualization of knowledge.

Data visualization is not a modern concept. Centuries ago, it was used by scientists to record the results of their research in detail. Modern technologies make it possible to consolidate more and more data, process them more thoroughly and present them in a convenient format for display. Every day the visualization becomes more and more relevant.

[25] Бобрицька, В. І. (2011). Освітня політика України у сфері інформатизації освіти. Освітня політика, філософія, теорія, практика [монографія] / За ред. В. П. Андрущенка; Авт. кол. В. П. Андрущенка, В. І. Бобрицька, Р. М. Вернидуб ін. – К.: Вид-во НПУ Імені М. П. Драгоманова. 273-316.

[26] Краснопольський, В. Е. (2010). Віртуальна реальність як нова форма освітнього простору. Сучасні інформаційні технології та інноваційні методики навчання в підготовці фахівців: методологія, теорія, досвід, проблеми. 23.

The expediency of using the visualization of knowledge is dictated by the modern need to present them in a form most convenient to the new needs of current learning. Psychologists characterize this generation as a new culture of knowledge perception, which is formed as a reaction to the rapid growth of information flows, mainly in visual form. Signs of such thinking are the ability to quickly switch between semantic fragments, high speed information processing, preference for the perception of information in figurative form, but at the same time maladaptation to the perception of linear, homogeneous current information, including large books[27]. Due to visualization, educational information coming through different channels of perception is transformed into a visual form and due to the most effective ways of working with the material significantly increases the speed of processing and assimilation[28]. Considering the prerequisites for the use of visualization in the educational process or in the implementation of research and science-intensive projects by students, we note that it contributes to the formation of students' correct ideas about the object under study. Note that without the use of visualization, it is difficult to avoid students' misconceptions about the object of study, and this creates problems for them to understand both in the early stages of the project and later. In the didactic aspect, AR Raputa sees the importance of visualization in the ability to "indirectly and visually represent the studied phenomena in those areas in which direct visual perception is difficult or impossible"[29]. Given the fact that the content of research and science-intensive projects in the aviation industry includes a lot of research material of an abstract nature, involves the study of objects and phenomena of various natures, including non-renewable or non-renewable under normal conditions. Thus, the use of visualization in the learning process becomes necessary. AV Polyakova reveals the role of visualization in research[30] as a powerful factor in the actualization of different types of thinking and human memory. The author notes that visualization allows to actualize not only figurative, associative and other types of thinking, but also complements and develops auditory perception in verbal learning and activates such types of memory as verbal-logical, visual, emotional, etc. An important consequence of this influence is that it stimulates the student to comprehend, generalize, clarify the perceived images, ensures the completeness and integrity of their perception.

Theoretical foundations of visualization of educational information are presented in the works of O. G. Asmolov, F. C. Bartlett, A. O. Verbitsky, V. V. Davydov, P. M. Erdniev, Z. I. Kalmykova[31] and others. Specialists in the theory of cognition, teachers, psychologists, culturologists (Z. Belova, G. Gardner, N. Manko, K. Frumkin, M. Kholodna and others) study relatively stable individual features of human cognitive processes and ways to take them into account in the learning process, pay attention to the heuristic potential of visualization. Peculiarities of visualization application in the educational process were studied by S. Aryutkin, G. Bryantseva, V. Koibichuk, S. Gerasimova, V. Kuzovleva, E. Makarova, N. Manko, I. Margolina, E. Polyakova, N. Neudakhina, A. F. Pukhov, A. G. Raputo, N. Neudakhina[32], O. Rodey, S. Selemenev, S. Sergeev, V. Chetin, D. Shekhovtsova and others. L. I. Doliner, M. I. Pak, N. G. Semenova, V. Starodubtseva proposed ways to organize the educational process using computer visual learning materials. O. Mansurova, A. Sobolev, B. Starychenko, S. Shushkevych devoted their work

[27] Науменко, О. М. (2011). Основні ознаки комп'ютерно орієнтованого освітнього середовища і шляхи його формування. Інформаційні технології і засоби навчання. Електронне наукове фахове видання 4 (24).

[28] Бобрицька, В. І. (2011). Освітня політика України у сфері інформатизації освіти. Освітня політика, філософія, теорія, практика [монографія] /За ред. В. П. Андрущенка; Авт. кол. В. П. Андрущенка, В. І. Бобрицька, Р. М. Вернидуб, ін. – К.: Вид-во НПУ Імені М. П. Драгоманова. 273-316.

[29] Struktura IKT-kompetentnosti uchitelei. Rekomendatcii UNESCO (2011). [The structure of the ICT competence of teachers. UNESCO Recommendation] // UNESCO. – 116.

[30] Raputo, A. G. (2010). Vizualizatciia kak neotemlemaia sostavliaiushchaia protcessa obucheniia prepodavatelei [Visualization as an integral component of the teacher training process] Mezhdunarodnyi zhurnal eksperimentalnogo obrazovaniia. 5. 138-141.

[31] Kalmykova, Z. I. (1981). Produktivnoe myshlenie kak osnova obuchaemosti [Productive thinking as a basis for learning]. Pedagogika. 200.

[32] Raputo, A. G. (2010). Vizualizatciia kak neotemlemaia sostavliaiushchaia protcessa obucheniia prepodavatelei [Visualization as an integral component of the teacher training process] Mezhdunarodnyi zhurnal eksperimentalnogo obrazovaniia. 5. 138-141.

to the development of new methods, the creation of original methods of computer visualization of educational material, and its application in the teaching of specific disciplines. In the works of L. Bilousova, V. Kastornova, I. Kosenko, S. Lozovenko, E. Malkina, M. Nekrasova, L. Sidorova, A. Tumalev the issues of teaching future teachers methods of designing and developing electronic didactic resources are considered. However, in the UNESCO document "Structure of information and communication technologies – the competence of teachers. The UNESCO recommendations state that in the twenty years since the widespread introduction of computers in education, we have learned a lot about information and communication technologies, about their potential for the transformation of national educational systems. There are different countries in all parts of the world, and today they face the everyday problems of informatization of higher education, which is difficult to solve. Such problems arise due to the rapid development of technology and weak financial security. Teachers also do not have a clear vision of how to use the power of information and communication technologies to transform the educational process in higher education and beyond[33]. In the context of rapidly growing volumes of information and the pace of knowledge presentation, the use of new effective methods of presenting educational information in education becomes especially important. There is a need for new research that will systematize the accumulated practical experience and substantiate scientific approaches to solving these problems using the capabilities of modern imaging technologies. The term "visualization" (derived from the Latin visualis, meaning "visual") has different interpretations in the psychological and pedagogical literature in relation to knowledge, information. In this paper we will use the concept of visualization in a broad sense. Visualization is determined by techniques and methods that present the necessary information in a form convenient for visual observation. Visualization of educational information is motivated, firstly, by the need to present it in a form that will best meet the new needs of the current generation of students. Psychologists and culturologists characterize the new generation in terms of their new culture of information perception, calling them "screen people" with a new type of thinking. A large amount of short-term information forms the so-called "clip" thinking, which is a reaction to the rapid growth of information flows, coming mainly in visual form, high fragmentation, a great variety of modern information technology and information diversity. Culturologist K. Frumkin notes the peculiarities of such thinking as the ability to quickly switch between disparate semantic fragments. In addition, he notes the high speed of information processing and the advantages of perceiving information in figurative form. He also emphasizes the inability to perceive linear, homogeneous information that can be presented in the form of long book texts. The researcher believes that such thinking "is more in line with the information environment in which the student lives"[34]. Features of the visual system underlie the visualization of educational information, as well as the innate ability of the human brain to work effectively with visual images. The human visual system is considered to be the internal channel of communication between all analyzers, as well as the functional organ that converts signals. Therefore, it is the most important source of information about the world around us. Educational information coming through different channels of perception is transformed into a visual form. Due to the most effective ways to work with it, you can increase the speed of processing and assimilation of the material.

Another interpretation of the term "visualization" is to create an image of the object under study, in particular the demonstration of the image – this is not the only issue that is being addressed. From this point of view, the term "visualization" can be interpreted as a specific category of didactics, which has a more complex structure. The traditional concept of "clarity" does not include in the work of the teacher actions related to the construction of the image of objects or phenomena being studied. Therefore, the main purpose of visualization will be the inclusion

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[33] Struktura IKT-kompetentnosti uchitelei. Rekomendatcii UNESCO (2011). [The structure of the ICT competence of teachers. UNESCO Recommendation] // UNESCO. – 116.

[34] Raputo, A. G. (2010). Vizualizatciia kak neotemlemaia sostavliaiushchaia protcessa obucheniia prepodavatelei [Visualization as an integral component of the teacher training process] Mezhdunarodnyi zhurnal eksperimentalnogo obrazovaniia. 5. 138-141.

of mechanisms of imagination, installation and consolidation of associative links between visual images and the nature of basic concepts. Thus, analyzing the approaches in the interpretation of the term "visualization", we can conclude that there is a unity of opinion about the perception of an object through sight, ie through a visual image. The term "visualization" comes from the English word visualization, so we will interpret it as a process of demonstrating educational material that requires the construction of a visual image, not just its reproduction. To teach the teaching material, teachers needed a pencil and paper or chalk and a board, the modern arsenal of teacher's tools included the latest technical innovations such as interactive whiteboards, projector, reader, tablet, etc. The availability of computer technology and the growing number of powerful educational applications have contributed to the active introduction of information technology in teaching and work on research and science-intensive projects.

It is worth noting that there are many special tools for creating visualizations. Some of them are very easy to use: you just need to download the data and choose how it will be displayed, but other programs are more difficult to use. They are often complex, ie require special knowledge and programming skills.

One of the effective visual tools is a "virtual laboratory" as a software tool for conducting and demonstrating research and science-intensive projects.

Analysis of current research has shown[35] that there are a large number of virtual laboratories that contribute to the information and analytical support of scientific activities, used in the development of methods and software products for teaching. In addition, virtual laboratories can act as a software and hardware complex of practical use of research results when working on research and science-intensive projects.

According to V. Trukhin[36], virtual laboratories are software that allows project execution under simplified conditions, without direct contact with the installation. This allows you to work on the project at the same time the required number of students who can be in the distance learning process. K. I. Bogatyrenko considers time to be a significant advantage of virtual laboratories over traditional approaches when working on research projects. It should be noted that virtual laboratories can significantly reduce the time to develop the necessary materials and focus students on studying the methods of research theory and analysis of the results.

The advantages of virtual laboratories should be noted: no need to purchase the necessary equipment. The current lack of funding in many laboratories requires the use of old equipment that does not meet the latest requirements in the IT industry and sometimes distorts the results of experiments. Ability to model processes, the course of which is not possible without certain equipment; the ability to penetrate processes that take place at a different scale with different values of input data and save scale time are integral components of research and science-intensive projects. It should also be noted that another significant advantage of virtual laboratories is the time spent collecting the project.

When conducting a project in a virtual laboratory, the student has the opportunity: individual performance skills, development of his technical intelligence and responsibility. This forms a competence that can not but affect the development of independence of the future specialist.

The main value of virtual laboratories is its content. Biptyal processes, which reflect a certain physical process on the computer screen, are always secondary in accordance with the subject reality. This ensures the reality of the material world, where objectively and independently of the observer there is a real process. It was noted by the director of the Center for Virtual Science

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[35] Purzer, S. (2017). Engineering approaches to problem solving and design in secondary school science: Teachers as design coaches. A Paper Commissioned by the National Academies of Sciences, Engineering, and Medicine Science Investigations and Engineering Design for Grades. 6-12.

Briantseva, H. V. (2011).Vizualizatsiia navchalnoho materialu z kompiuternoi hrafiky za dopomohoiu asotsiatyvnykh zobrazhen-obraziv [Visualization of educational material on computer graphics using associative images] Briantseva H. V. Osvita Donbasu. #6. 53-59.

[36] Raputo, A. G. (2010). Vizualizatciia kak neotemlemaia sostavliaiushchaia protcessa obucheniia prepodavatelei [Visualization as an integral component of the teacher training process] Mezhdunarodnyi zhurnal eksperimentalnogo obrazovaniia. 5. 138-141.

of the Human Institute of Humanities (PAH), the doctor of psychological sciences, Professor M. A. Hocov. Therefore, it should be noted that the results of overhead lines must undergo a two-stage analysis for the transition from the information obtained during the work in the virtual laboratory to the formulation of the latest fact. M. A. Hocov noted that the virtual reality has the features of reality, which is relevant only "here and now", that is, only when the virtual process is launched. Thus, the virtual laboratory is a computer.

Consider the features of the use of virtual laboratory in the formulation of adequate conclusions when working on research and science-intensive projects. Regarding the real fact, it is necessary to note such features as completeness, sufficiency, uniqueness to determine the level of preparation of the mathematical model, which gives rise to a vital process. The mathematical model participates in the management of events with "virtual" objects, which is performed by the cadet in the process of performing virtual laboratory.

In the process of professional training of students, you can use both virtual laboratories, workshops, modeling environments, and entire virtual worlds.

In the conditions of distance learning, virtual worlds have become powerful modern means. They use integrated multimedia environments that allow students to perform tasks at a new level of perception. When comparing the virtual world with the real world, which has certain limitations, such as cost, location and timing, virtual reality is a perfect system without limits. Virtual reality systems can serve as a basis for joint learning of students, as well as for feedback from the teacher. If typical paper resources are limited, then virtual worlds depend only on electricity.

V. E. Krasnopolsky noted that there are different types of virtual reality systems. They differ in the ways and modes of their interaction with the user[37]:

a) Desktop Virtual Reality (Desktop VR) and WWW systems are programs that allow you to use your computer in virtual reality;

b) Video Mapping is a projection technology that is a 3D projection on a physical object of the environment, taking into account its geometry and location in space, ie the user looks at the screen and sees his silhouette. This is done with a video camera. The user's silhouette is superimposed on a two-dimensional image created by a computer;

c) Immersive Systems – perfect virtual reality systems that mimic the interaction with the virtual environment by affecting all five human senses, while creating a sense of presence. Programs provide a plausible simulation of the virtual world with a high degree of detail. The immersion effect is provided by the use of a high-performance computer and special equipment;

d) remote presence systems are systems that do not provide full immersion, but in virtual worlds well-organized interaction with other users of virtual reality. The systems work by connecting remote sensors;

e) Mixed Reality is a system of combining real and virtual worlds, where the real world is transformed into a computer image, and physical and digital objects coexist and interact based on information output from remote presence sensors.

Consider in more detail some of these methods. The latest Mixed Reality information technology, for example, is appropriate for students to use when working on projects. It is known that applied research in the aviation industry is a project aimed at obtaining and using new knowledge for practical purposes in aviation. Theoretical and practical knowledge gained by students as a result of applied research can be used to create new or improve existing products, devices, methods, technologies and systems in aviation, and systems for combining real and virtual worlds do not require modern material and technical bases and equipped laboratories.

When working with virtual world systems, certain abbreviations are used, such as MR, VR and AR. There are also characteristics that help to easily distinguish between "types" of reality and not to be confused with each other.

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[37] Там само.

The real world is an objective reality that does not use artificial technology. Virtual reality is a system that is represented by screens, holograms and other artificial means. AR is an augmented reality or a real world in which clues, holograms and more are attached to each object. In addition, AR is a virtual world that is built on the basis of the real and is subject to it in everything.

Mixed reality applications must be distinguished from AR reality applications. Virtual objects in mixed reality systems can be applied to real world objects, ie real objects control the work of virtual ones. Augmented reality is completely subordinate to the real.

As you know, the development of science-intensive projects is based on real objects, so the combination of virtual and real world is considered a hybrid technology, defined by the name MR. The peculiarities of mixed reality technologies include the following: real and virtual worlds are mixed, they can not be clearly distinguished. With the help of MR technology it is possible to develop research projects based on simulations, as well as projects in which training takes place without increased risks. In addition, the technology allows you to create an interactive environment with full integration of virtual objects into reality.

3D printing technology in universities.

3D printing technology is a powerful modern learning tool that can engage students in active learning, design thinking and problem solving. It creates opportunities for the integration of science, technology, engineering and mathematics with other disciplines. However, for a long time 3D printing was not available for training. There are several reasons for this situation.

3D printing technology has long been considered high technology in the field of information technology, which is very complex, expensive, and therefore most believed that it was something inaccessible. The development of information technology has changed this view. Today, 3D printing is an attractive technology that is a simple and interesting modeling tool. Every day, building a 3D model becomes more accessible, the learning experience is spreading globally.

Research and science-intensive projects are no exception. Students can also master the additive technique, in which all three-dimensional objects are created by applying successive layers of materials. The only question is to buy a desktop 3D printer and its basic elements to assemble your own home 3D printer. This promising new technology has opened up virtually limitless possibilities for scientists and students to model, prototype and create unique objects. Consider the main aspects of 3D printing technology separately.

Creating a model in science-intensive projects remains one of the important methods of scientific knowledge among the special methods of scientific research. It is used to study individual aspects of an object. Each model is to some extent a specific form of reflection of reality, so the study of objects and its properties through modeling is possible. A model is a simplified real object that helps a scientist reproduce parts of a project.

Another aspect of 3D printing technology is prototyping. Rapid prototyping can be considered the initial goal of sample development and the second name of the technique. Creating research objects in the implementation of research projects using 3D printing significantly reduces the time and cost of the project. Thus, prototyping allows you to clearly assess the possible shortcomings of the sample at the design stage. The scientist has the opportunity to make the necessary changes in the design of the part in the process of working on the project.

A further aspect of 3D printing technology is the creation of exclusive models. The technological process of printing three-dimensional objects allows you to demonstrate all the necessary details of the sample, which is the object of research or science-intensive project.

The next important aspect of making products on a 3D printer is the use of different materials. PLA biopolymers and ABS plastic are considered to be popular materials, which make it easy to create functional prototypes of samples and complex finishes. Note that the transparent material allows you to see the work of functional details from all sides at the same time, which is very useful in the development of research projects.

Theoretical foundations of 3D printing technology in the educational process.

The principles of integrating 3D printing technology into the educational process are based on engineering approaches to solving problems aimed at increasing the value of science, technology and engineering to "reflect real research and engineering design in the learning process"[38]. Learning models developed within this area emphasize design-based learning that promotes the study of science through design.

The process of creating 3D printed objects involves designing a 3D model of the desired object using automated design software and printing the object using a 3D printer. This technology is becoming more readily available and affordable for high-tech projects by lowering the cost of desktop 3D printers and the availability of open source software applications for users with a variety of 3D modeling skills. 3D printing technology can be a powerful educational tool, opening to students an iterative design cycle that is central to practical engineering.

However, research on the potential for integrating 3D printing technology into formal STEM education is extremely small. Although 3D printing is implemented in various non-formal educational institutions, such as libraries, extracurricular programs and museums, there has been little research on how this innovative technology can provide students with new concepts of engineering, technology and science. A recent review of the literature of Papaulasopoulos et al.[39], where an empirical study of the makers 'movement showed that there is a broad interest in the makers' movement. The latest technologies involve people in the process of creating digital and non-digital artifacts with a variety of tools and technologies such as 3D printing, electronics, robotics, and physical computing platforms. The authors reported that there is widespread interest in the makers' movement. However, thorough and reliable empirical research on the movement of manufacturers and, in particular, 3D printing, is very limited. Of the selected 43 peer-reviewed peer-reviewed articles, only two examined the educational benefits of 3D printing[40]. Typically for the newborn field of educational technology research, most of which relates to research on student-centered learning, a qualitative methodology was used to study the various learning processes and outcomes.

In general, the literature shows the positive impact of 3D printing and design technologies on the attraction and perception of students. In addition, regardless of the demographic characteristics of students, creation-oriented learning has been a positive and successful experience in various fields of application. However, the mere availability of 3D printing technology is not enough for teachers to use its potential in science-intensive projects. It should be combined with the content, based on practical activities that correspond to development, and systematically integrated into the educational process[41].

Research has also shown that teachers need to be introduced to 3D printing technology. In addition, there are very few empirical studies on teacher training for the integration of 3D printing technologies in teaching[42]. Today, there are only seminars for teachers on 3D printing technologies and 3D modeling of literary documents. However, researchers in higher education agree that 3D printing can support learning, creativity and interest in working on science-intensive projects, particularly in the aviation industry.

Over the last few years, there have been many ideas for one-off projects, seminars and even courses related to 3D printing. Large 3D printing companies have recognized the need

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[38] Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to Learn About Complex Systems. Journal of the Learning Sciences, 9 (3), 247-298.

[39] Quin, H., & Bell. P. (2013). How designing, making and playing relate to the learning goals of K-12 science education. In M. Honey & D. E. Kanter (Eds). Design. Make. Play: growing the next generation of STEM innovators. New York. NY: Routledge. 17-33.

[40] Papavlascpoulou, S., Giannakos, M. N., & Jaccheri. I. (2017). Empirical studies on the maker movement, a promising approach to learning: a literature review. Entertainment Computing. 18, 57-78.

Leduc-Mills. B., & Eisenberg. M. (2011). The UCube: a child-friendly device for introductory three-dimensional design. In Paper presented at the proceedings of the 10th International conference on interaction design and children. New York: ACM.

Sullivan. P., & McCartney. H. (2017). Integrating 3D printing into an early childhood teacher preparation course: Reflections on practice. Journal of Early Childhood Teacher Education. 38 (1). 39-51.

[41] Malou. R., Trust. T., Kommers. S., Malinowski. A., & LaRoche. I. (2017). 3D modeling and printing in history/social studies classrooms: initial lessons and insights. Contemporary Issues in Technology and Teacher Education. 17 (2).

[42] Stratasys Launches 3D Printing Education Modules. (2016). CAD/CAM Update, 28 (2), 2-4.

for a curriculum and offer free modules for teachers to "guide students through the full life cycle of product development, from concept sketching to CAD design and finally 3D printing"[43].

Researchers are constantly pointing out the potential of 3D printing to achieve new learning goals and when working on science-intensive projects. The goal of higher education today is to train 21st century professionals, but that means preparing students for the world of the unknown. Baden et al. Explained: "One of the common issues in building a sustainable research infrastructure and science culture in countries with limited resources is the constraint on career choices provided by higher education"[44]. Open 3D printing is a great barrier to closed thinking at home and abroad.

Advantages of using 3D printing technology when working on science-intensive projects.

When it comes to creating a research project, what scares away ambitious scientists is the exorbitant cost of laboratory equipment. However, these barriers are being overcome by increasing the availability of 3D printers that can create equipment from projects published online. In addition, 3D printing technology can be used to create laboratory equipment that was previously too expensive for individual scientists or small laboratories.

For example, a centrifuge is very important even for the simplest laboratory experiments, but buying it from the manufacturer can be expensive. Using a 3D printer and a free design from an open source hardware database, labs can now create several at a fraction of the cost of purchasing one.

Scientists are now creating innovative laboratory equipment projects that can be used online and printed at an affordable price. This will make it possible to equip third-world universities and laboratories with equipment that would otherwise never be available to them. This increases the opportunities for work on science-intensive and research projects.

Increasing the availability of 3D printing is also revolutionizing the production of prototypes that were previously valuable at every stage of development. Now a student with 3D printing technology can print prototypes at every stage, finding out what works and what doesn't, for a small fraction of the cost.

Open source sharing sites allow students to work in a team and model new projects created from print parts that are available online, or modify existing projects to achieve a different function. As 3D printing technology becomes more accessible, trial and error design will become possible in higher education, DIY labs, removing many barriers to innovation. 3D printing is likely to change our way of developing objects and ideas forever.

Using 3D models in project work allows students to gain more practical experience. In addition, 3D printing technology allows students to tailor their work directly to the needs of the project and focus on creating new science-intensive technologies that students need more time to understand.

It is one thing to read about methodologies in a textbook, but it is another to have a three-dimensional model that you can physically touch and move. With a 3D printer in high school, students can pinpoint the area in which they have difficulty understanding and influence them in a new way.

Simply put, 3D printing attracts the attention of both students and teachers. And as students' attention spans become shorter and harder to maintain, 3D printing technology is emerging to breathe new life into science-intensive projects.

3D models engage students and help them understand complex or advanced concepts and skills. Technology can also be adapted to students' learning styles. Some students learn visually and tactilely, and seeing the model or holding it in their hands, they can quickly or more fully understand.

Another aspect of the use of 3D printing technologies should also be noted. Simulation helps students understand how technology really works in the aviation industry. In particular, design students who directly created, reviewed or analyzed a prototype in the work will be miles ahead

[43] Baden, T., Chagas, A. M., Gage, G., Marzullo, T., Prieto-Godino, L. L., & Euler, T. (2015). Open Labware: 3-D Printing Your Own Lab Equipment. Plos Biology, 13 (3), 1-12.

[44] Crismond, D. (2013). Design practices and misconceptions. Science Teacher, 80 (1), 50-54.

of those students who did not have such an opportunity. 3D printers give students a better idea of the actual professional uses of objects and help them move forward on a project faster.

Consider the modern technology Design TM[45], which is designed to provide recommendations for the creation of a learning unit that includes 3D printing technology.

Design TM technology is a project-based approach to science education based on object-specific and problem-based learning. Originally designed for non-digital design, it promotes science through design. Linking project activities to scientific content creates many problems for high school teachers for several reasons. First, there are many barriers to linking engineering and science education, including a lack of resources and methodologies for integrating engineering into the education system. Second, many teachers do not have the necessary technical knowledge.

Design TM technology focuses on the sequence of actions for successful design-based learning[46] and includes the following features:

1. Effective presentation of the design task, including supporting materials and resources that promote learning and project development.
2. Includes reflection and planning to help students keep track of their design ideas, problems and plans.
3. Carries out planning and includes research activities to help with a deeper study of some of the major subgroups of problems identified earlier, to share their findings through some reflective activity.
4. Evaluates the project task based on the results of research activities and invites students to present their work to others.
5. Includes numerous design/design iterations and testing to reach a solution along with discussions and presentations.
6. Includes final presentation, demonstration and reflection.

This learning technology turns project work into a process where students become "reflective decision makers" and teachers act as "design trainers"[47].

Recommendations for designing and planning a 3D printing project.

To help students and teachers develop, plan and implement a 3D printing project, it is advisable to follow the following recommendations:

1. Select the required standard: Before creating a 3D printing project, select the appropriate standard to be used in the project. Because 3D printing requires certain skills across disciplines, standards need to be considered in several areas.
2. Identify the design problem: select the object to be printed in 3D, its intended use, target audience and the real environment in which the object will be used. Once the relevant standards have been determined, they should be considered
    - an object or several objects that students will design;
    - The 3D printing technology that the 3D printing object will use.

Choosing the right object for those who plan to work on the project is crucial for successful 3D printing. When identifying possible objects, it is important to take into account the previous experience and skills of 3D modeling of the student, as well as familiarity with the object, its functionality, use in the real world and the environment in which the selected object will be used. For example, choosing an object with a complex design and structure requires advanced 3D modeling skills, difficult to implement for inexperienced teachers or students.

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[45] Quin, H., & Bell. P. (2013). How designing, making and playing relate to the learning goals of K-12 science education. In M. Honey & D. E. Kanter (Eds). Design. Make. Play: growing the next generation of STEM innovators. New York. NY: Routledge. 17-33.

[46] Papavlascpoulou, S., Giannakos, M. N., & Jaccheri. I. (2017). Empirical studies on the maker movement, a promising approach to learning: a literature review. Entertainment Computing. 18, 57-78.

[47] Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to Learn About Complex Systems. Journal of the Learning Sciences, 9 (3), 247-298.

Another important factor is how the 3D print object will be used. It is important to choose an experimental scenario, environment, or settings that can provide feedback on the functionality of the object.

When working with a 3D printer, it is important that students have some understanding of the functionality and design of the object, as well as an understanding of how their 3D printed object will be used.

3. Identify resources for students to understand the finished 3D print object, including its design, functionality, and vocabulary for a particular subject. It is important that students understand the subject well before participating in the design process.

For example, to design an aircraft element for a scientific experiment, students need to know the general types of aircraft, their basic design elements, and a special vocabulary to convey their aircraft designs. Therefore, an important step in developing and planning a 3D printing project would be to identify resources that will help students learn about the finished object.

4. Definition of relevant subject knowledge of the content. Once the design task is selected, students need to determine some knowledge of the content of the object in order to successfully complete a 3D printing project. Reading materials, relevant websites, etc. should be provided to increase students' knowledge of 3D printing science, technology, and other content.

5. Students' understanding of the design process. Studies have repeatedly shown that novice designers demonstrate a set of common design errors that negatively affect their design experience and participation in the design process[48]. Most design errors are based on the fact that when working on projects:

- students focus on clearly defined problems with one right solution;
- do not include reflective, iterative design processes[49].

In addition, beginning students often have difficulty gathering information and posing problems when working with the first projects[50]. The literature suggests that teachers should help beginning students to develop sound design methods and suggest several design methods that can be used to achieve the ultimate goal[51] (Fig. 1). Modeling supports the iterative process of design and mapping, so practical design methods must be used judiciously.

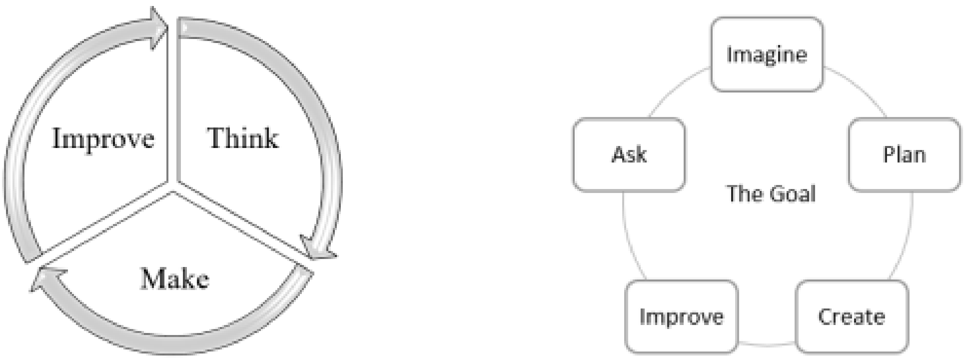

Fig. 1. Design methods

[48] Там само.
[49] Alemdar, M. Lingle, J.A., Wind, S.A., & Moore, R. A. (2017). Developing an engineering design process assessment using think-aloud interviews. International Journal for Engineering Education, 33 (1), 441-452.
[50] Martinez, S. L., & Stager, G. (2013). Invent to learn: Making, tinkering, and engineering in the classroom. Torrance: Constructing Modern Knowledge Press.
[51] Hong, Y.-C., & Choi, I. (2018). Relationship between student designers' reflective thinking and their design performance in bioengineering project: exploring reflection patterns between high and low performers. Educational Technology Research and Development.

6. Identify appropriate SAD software and training resources. There is a wide selection of CAD software for users with different skills and needs in 3D modeling technology. Appropriate CAD software and study materials based on 3D modeling skills and student needs should be selected. If students are just beginning to work with 3D modeling and 3D printing, it is useful to choose software that is easy to use. Preparing students to use SAD software will help them feel comfortable with 3D modeling and allow them to create high-quality design projects. Enabling students to see the 3D printer in action will allow them to estimate the time spent completing the printing of their object.

7. Establish procedures and structures to support student learning and reflective activities. Reflective thinking is one of the key elements underlying the design process[52]. This allows students to control decision-making, track unfamiliar and new design tasks, use their previous experience to develop partial solutions from previous cases and move between different stages of design[53]. Thus, it is important to establish procedures and structures that help students reflect on the entire design process. This can be done through student presentations, class discussions, expert assessments, a scientific journal and reflective writing. These activities will support students' communication and scientific literacy skills[54]. In addition, progress reports, presentations and reflections can be used as a formative assessment. This will help track and manage students' work on the project.

8. Creating a schedule of 3D printing technology project. You need to perform several design iterations and then test them. At the beginning of the work, when the student has decided which 3D printing technology project he is going to implement and what resources and materials he needs to support the student's work on the project, it is time to work on creating a 3D printing technology project schedule. It is difficult to overestimate the importance of proper project planning for a successful project. It is important to think about how long it will take a student to master certain skills and knowledge of content, to study the design process, research ideas for artifacts of their projects, create and test their physical prototypes, learn to use CAD software, 3D modeling technology and 3D printing technology. their artifacts, testing them and reviewing the design as needed.

9. Complete the 3D printing technology project with a final presentation, demonstration or experiment and include reflection. Communication is an important skill when working on research and science-intensive projects. Some scholars argue that science and engineering cannot develop or create new or improved technologies if the findings and benefits of new designs cannot be clearly and convincingly communicated to others[55]. Students who are satisfied with the result of their work, namely the object they designed and printed with a 3D printer, will be happy to share with others, as well as what they learned in the design process and how they solved problems. Therefore, students should be given the opportunity to describe their path to solving the problem and the results they obtained, as well as provide evidence to support the decisions they made during the iteration.

Conclusions. The analysis of electronic resources showed that the result of work on research and science-intensive projects is directly related to the success of students, their expectations from work in design and their beliefs about the value of research[56]. This conclusion confirms the idea of using 3D printing as an innovative and effective way of working in design. 3D technologies are the most popular in technical universities. Students can design objects, parts and layouts, prototype with 3D printers, evaluate and test them. 3D printing technologies enable future specialists in the aviation industry to implement their design ideas and projects.

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[52] Schön, D. A. (1987). Educating the reflective practitioner: Toward a new design for teaching and learning in the professions. San Francisco: Jossey-Bass.

[53] OECD (2016), PISA 2015 Results (Volume II): Policies and Practices for Successful Schools, PISA, OECD Publishing, Paris.

[54] Bybee, R. W. (2018). STEM Education Now More Than Ever. NSTA Press: Arlington, VA.

[55] Smith, R. C., Iversen, O. S., & Hjorth, M. (2015). Design thinking for digital fabrication in education. International Journal of Child-Computer Interaction, 5, 20-28.

[56] Bybee, R. W. (2018). STEM Education Now More Than Ever. NSTA Press: Arlington, VA.

Visualization of educational material performs the function of forming professional competence. The student must have not only an understanding of the mathematical, informative, natural foundations of the process of dynamic visualization, but also mastering computer tools. This helps to form the correct ideas of students about the object of study when working on the project; gives the opportunity to focus students' attention on the main content elements of the project material, highlighting them in the visual image and at the same time filtering out secondary and unnecessary details.

References

1. Alemdar, M. Lingle, J. A., Wind, S. A., & Moore, R. A. (2017). Developing an engineering design process assessment using think-aloud interviews. International Journal for Engineering Education, 33 (1), 441-452.

2. Baden, T., Chagas, A. M., Gage, G., Marzullo, T., Prieto-Godino, L. L., & Euler, T. (2015). Open Labware: 3-D Printing Your Own Lab Equipment. Plos Biology, 13 (3), 1-12. doi:10.1371/journal.pbio.1002086.

3. Briantseva H. V. (2011).Vizualizatsiia navchalnoho materialu z kompiuternoi hrafiky za dopomohoiu asotsiatyvnykh zobrazhen-obraziv [Visualization of educational material on computer graphics using associative images] Briantseva H. V. Osvita Donbasu. #6. 53-59. (In Ukrainian).

4. Bybee, R. W. (2018). STEM Education Now More Than Ever. NSTA Press: Arlington, VA.

5. Crismond, D. (2013). Design practices and misconceptions. Science Teacher, 80 (1), 50-54.

6. Hmelo, C. E., Holton, D. L., & Kolodner, J. L. (2000). Designing to Learn About Complex Systems. Journal of the Learning Sciences, 9 (3), 247-298.

7. Hong, Y.-C., & Choi, I. (2018). Relationship between student designers' reflective thinking and their design performance in bioengineering project: exploring reflection patterns between high and low performers. Educational Technology Research and Development.

8. Kalmykova, Z. I. (1981). Produktivnoe myshlenie kak osnova obuchaemosti [Productive thinking as a basis for learning]. Pedagogika. 200. (In Russian).

9. Leduc-Mills. B., & Eisenberg. M. (2011). The UCube: a child-friendly device for introductory three-dimensional design. In Paper presented at the proceedings of the 10th International conference on interaction design and children. New York: ACM.

10. Malou. R., Trust. T., Kommers. S., Malinowski. A., & LaRoche. I. (2017). 3D modeling and printing in history/social studies classrooms: initial lessons and insights. Contemporary Issues in Technology and Teacher Education. 17 (2).

11. Martinez, S. L., & Stager, G. (2013). Invent to learn: Making, tinkering, and engineering in the classroom. Torrance: Constructing Modern Knowledge Press.

12. OECD (2016), PISA 2015 Results (Volume II): Policies and Practices for Successful Schools, PISA, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264267510-en.

13. Papavlascpoulou, S., Giannakos, M. N., & Jaccheri. I. (2017). Empirical studies on the maker movement, a promising approach to learning: a literature review. Entertainment Computing. 18, 57-78.

14. Purzer, S. (2017). Engineering approaches to problem solving and design in secondary school science: Teachers as design coaches. A Paper Commissioned by the National Academies of Sciences, Engineering, and Medicine Science Investigations and Engineering Design for Grades. 6-12.

15. Quin, H., & Bell. P. (2013). How designing, making and playing relate to the learning goals of K-12 science education. In M. Honey & D. E. Kanter (Eds). Design. Make. Play: growing the next generation of STEM innovators. New York. NY: Routledge. 17-33.

16. Raputo, A. G. (2010). Vizualizatciia kak neotemlemaia sostavliaiushchaia protcessa obucheniia prepodavatelei [Visualization as an integral component of the teacher training process] Mezhdunarodnyi zhurnal eksperimentalnogo obrazovaniia. 5. 138-141. (In Russian).

17. Schön, D. A. (1987). Educating the reflective practitioner: Toward a new design for teaching and learning in the professions. San Francisco: Jossey-Bass.

18. Smith, R. C., Iversen, O. S., & Hjorth, M. (2015). Design thinking for digital fabrication in education. International Journal of Child-Computer Interaction, 5, 20-28. doi:https://doi.org/10.1016/j.ijcci.2015.10.002.

19. Stratasys Launches 3D Printing Education Modules. (2016). CAD/CAM Update, 28 (2), 2-4.

20. Struktura IKT-kompetentnosti uchitelei. Rekomendatcii UNESCO (2011). [The structure of the ICT competence of teachers. UNESCO Recommendation] [Electronic resource] // UNESCO. – 116. Access mode: http://iite.unesco.org/pics/publications/ru/files/3214694.pdf. (In Russian).

21. Sullivan. P., & McCartney. H. (2017). Integrating 3D printing into an early childhood teacher preparation course: Reflections on practice. Journal of Early Childhood Teacher Education. 38 (1). 39-51.

22. Бобрицька, В. І. (2011). Освітня політика України у сфері інформатизації освіти. Освітня політика, філософія, теорія, практика [монографія] / За ред. В. П. Андрущенка; Авт. кол. В. П. Андрущенка В. І. Бобрицька, Р. М. Вернидуб, ін. – К.: Вид-во НПУ імені М. П. Драгоманова. 273-316.

23. Краснопольський, В. Е. (2010). Віртуальна реальність як нова форма освітнього простору. Сучасні інформаційні технології та інноваційні методики навчання в підготовці фахівців: методологія, теорія, досвід, проблеми. 23. [Електронний ресурс]. Режим доступу до журналу: URL: http://www.nbuv.gov.ua/.

24. Науменко, О. М. (2011). Основні ознаки комп’ютерно орієнтованого освітнього середовища і шляхи його формування. [Електронний ресурс]. Інформаційні технології і засоби навчання. Електронне наукове фахове видання 4 (24). Режим доступу: www.journal.iitta.gov.ua.