Didactic Principles Of Education Students 3D-printing

Iurii Lukianchuk[†] **Yurii Tulashvili**[††] **Volodymyr Podolyak**[†††] **Roman Horbariuk**[††††] **Vasyl Kovalchuk**[†††††] **Serhii Bazyl**[††††††]

[†,††, †††]Department of Computer Science, Lutsk National Technical University, 75 Lvivska, Str., 43018, Lutsk, Ukraine
[††††]Department of mechanical engineering and transport, Ternopil Volodymyr Hnatiuk National Pedagogical University, 2 Maxyma Kryvonosa Str., 46027, Ternopil,Ukraine
[†††††]Faculty of Technological and Professional Education, Oleksandr Dovzhenko Hlukhiv National Pedagogical University, 54 Kyevo Moskovska Str., 41400 Hlukhiv, Ukraine
[††††††]Separate Structural Subdivision "Shostka Vocational College named after Ivan Kozhedub of Sumy State University", 1 Instytutska Street, 41100 Shostka, Ukraine

Summary
The method of studying 3D-technologies abroad and in Ukraine is considered. The analysis of educational resources and experience of use of the equipment in branch is carried out. The didactic principles of the educational process for 3D-printing specialists are determined. The use of FDM technology and the ability to minimize the occurrence of defects in the future have been studied. An analysis of the international experience of the educational process of relevant specialists in the field. The content of training for 3D printing specialists has been developed. The experience of using 3D-technologies is described and the list of recommendations for elimination of defects during production of products by means of additive technologies is made. The recommendations will be useful not only for beginners, but also for experienced professionals in additive technologies. The need to study such experience is the main condition for the development of enterprises in Ukraine that plan to automate their own production. A 3D printing engineer must know the basics of economics and marketing, because his responsibilities include optimizing workflows to reduce the cost and speed up printing. Therefore, the knowledge gained from practical experience presented and in building for learning 3D printing engineers by the authors will be important.

Keywords: *software, education, content of training 3D-technologies, defects in 3D printing.*

1. Introduction

1.1 Need for the study

The modern information society is increasingly relying on the use of automated and robotic equipment, rapid prototyping technologies and software for designing technical facilities. Devices called 3D printers are increasingly entering the world market of modern technologies, changing our attitude not only to the concept of printing and modeling, but also to the production of various devices and elements in general. Additive technologies are widely used for prototyping and distributed production in architecture, construction, industrial design, automotive, aerospace, industrial, medical, bioengineering (for the creation of artificial fabrics) and many other areas of human activity.

The global market for additive manufacturing technologies (3D printing) in 2018 reached 12.8 billion US dollars, which is almost 2.5 times higher than in 2015 (5.2 billion dollars). At the same time, according to experts, by the beginning of 2022 the volume of the 3D printing market will reach 26.5 billion US dollars [1]. Therefore, today the IT industry needs qualified professionals with modern technologies, tools and equipment. Among them is a specialist who creates 3D models of products for their manufacture on automated equipment. In this regard, the issue of developing competence in the field of 3D modeling and 3D printing in the training process is relevant. This competence, as a consequence, increases the competitiveness of future skilled IT workers in the labor market.

The development of 3D printing technologies and their high prospects makes the issue of their application in educational activities especially relevant: as the education system prepares future generations for life in the information society and digital economy. Therefore, acquaintance of future specialists with advanced information technologies, namely, the basics of 3D printing within the modern educational process is appropriate.

Improving the educational process, 3D-technologies develop students' figurative thinking, teach them to 3D-programming and design. 3D printing significantly increases the interest in the learning process, as it allows students to feel like innovators in the chosen field of study.

Manuscript received July 5, 2022
Manuscript revised July 20, 2022
https://doi.org/10.22937/IJCSNS.2022.22.7.54

1.2 Literature review

The development of 3D printing technologies has been widely reflected in literary sources that reveal foreign experience. Engineers are finding practical applications for the use of 3D additive manufacturing. 3D printing allows new designs to become incredibly rare products that could not be achieved by traditional production methods. Various resources display data that are relevant for mastering 3D-printing technologies [2, 3].

The world experience of training specialists in 3D technologies is very diverse, but first of all it provides many information platforms where specialists share their own experience. Sabrie Soloman shows how the industry is changing with the spread of 3D printing technology [4]. H.N. Pandya's research describes the basics of working with additive technologies and reveals the experience of the educational institution, obtained from the results of practical training, which is collected in educational material for the training of 3D printing specialists [5].

In Ukraine at present, the experience of training specialists in 3D printing is minimal. Relevant specialists study mainly on their own through the acquisition and expansion of their own experience. When mastering the technology of 3D printing, as a rule, translations of world experience are used [6, 7].

There is no domestic literature with practical instructions on the use of 3D printing. Given this, it is important to analyze additive technologies in Ukraine and determine the knowledge base needed to master it.

1.3 Research objectives

Reveal the experience of the educational institution, obtained from the results of practical training for uses in educational material for the training of 3D printing specialists are research objectives.

2. Object, and methods of research

3D printing, which emerged in the 80s of the previous century, has been significantly modernized in its development. Today, this technology is used in many industries: in science, in industry, in medicine. To date, the advent of personal 3D printers has made this technology available to anyone.

The first successful experiment to create organs on a 3D printer took place in 2006. A team of bioengineers from the Wake Forest Institute for Regenerative Medicine (Vintson-Salem, USA) developed and printed bladders for seven subjects. Doctors used patients' stem cells to create an organ. Samples of donor tissue in a special sealed chamber with the help of an extruder was placed on top of the model of the bladder, heated to natural temperature of the human body. After 8 weeks, during intensive growth and subsequent cell division, the human organ was reproduced [8].

In 2010, the Fluid Interfaces Group of the Massachusetts Institute of Technology introduced the first 3D printer to create products - "Cornucopia" [9].

In 2013, Local Motors created a car printed on a 3D printer. Strati, consisting of 40 details that were printed in about 30 hours. The 3D-printer Big Area Additive Manufacturing, capable of working with a capacity of 4.5 kg of plastic per hour, was used [10].

As can be seen from the described technologies, now it is very important to develop skills in the future specialist in 3D technology. Therefore, it is especially important to study 3D modeling, prototyping and 3D printing in an educational institution. Classification of the main methods and technologies used in three-dimensional printing today are presented in table 1 [11].

Table 1: Classification of the main methods and technologies used in 3d printing

Method	Technology	Materials
Extrusion	Fused filament fabrication (FFF), fused deposition modeling (FDM)	Thermoplastic polymers (polyactide (PLA), acrylonitrile butadiene styrene (ABS) and others)
Wired	Electron-beam freeform fabrication (EBF)	Almost all metal alloys
Powder	Direct metal laser sintering (dmls)	Almost all metal alloys
	Electron beam melting (EBM)	Titanium alloys
	Selective laser melting (SLM)	Titanium alloys, cobalt-chromium alloys, stainless steel, aluminum
	Selective Heat Sintering (SHS)	Powdered thermoplastic polymers
	Selective laser sintering (SLS)	Thermoplastic polymers, metal powders, ceramic powders
Inkjet	Inkjet 3D printing (3DP)	Gypsum, plastics, metal powders, sand mixtures
Lamination	Laminating (LOM)	Paper, metal foil, plastic film
Polymeriza-tion	Stereolithography (SLA)	Photopolymers
	Digital LED Projection (DLP)	Photopolymers

Each technology has its own characteristics of application, there are a number of common factors for each of them. The printing methods presented in the table differ significantly in the principles underlying them, conditions of applicability, materials, shape and functional purpose of the products obtained with their help, it is worth studying each of the methods separately. Let's focus on the most common 3D printing technology - FDM.

A trained 3D printing specialist must have competence in many scientific and technological fields, but knowledge in several basic ones must be unconditional, such as learning the basics of 3D printing technology, namely: knowledge of the materials used; equipment and work technologies, study of methods for determining the optimal modes of the process; with software.

Layering (FDM / FFF) modeling, or extrusion, was developed by S. Scott Trump in the late 1980s and commercially available in 1990 by Stratasys.

The process of printing by layer-by-layer surfacing is the creation of layers by extrusion of material that hardens quickly in the form of microdroplets or thin jets.

As the most common and commercially available method of three-dimensional printing, the method of layer-by-layer surfacing has a wide range of consumables (filaments). Consider the main:

1. Polylactic acid (polylactic acid, PLA) is one of the most widely used polymers in 3D printing.

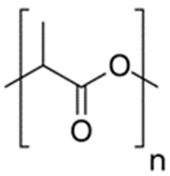


Fig. 1 Chemical formula of polylactic acid, PLA.

The prevalence of polylactide in additive production is determined by two factors. First, polylactide is completely safe for the environment. Secondly, because it is a polymer of lactic acid, polylactide is completely biodegradable. Among the few practical industrial applications of polylactide are the production of food packaging, drug containers and surgical sutures.

2. ABS plastic (Acrylonitrile butadiene styrene, ABS) - today it is the most popular polymer used in 3D printing.

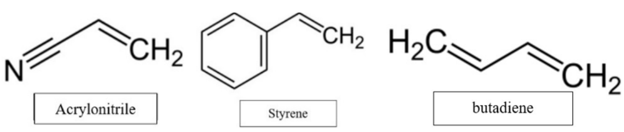


Fig. 2 Monomers for the synthesis of ABS plastic.

ABS plastic is a shock-resistant thermoplastic polymer. Widespread ABS -plastic is due to excellent mechanical properties, durability and low cost of this material. ABS - plastic has become widely used in industry.

In addition, ABS plastic is used as an additive that increases heat resistance and improves the digestibility of composite materials based on polyvinyl chloride (PVC), as an additive that increases the toughness of polystyrene, as well as an additive that reduces the cost of polycarbonate.

3. Polyethylene terephthalate (PETG) - a product of polycondensation of ethylene glycol with terephthalic acid. It is a solid colorless transparent substance in the amorphous state and white opaque in the crystalline state.

The material is used for the production of plastic bottles and other food and medical containers. Polyethylene terephthalate has high chemical resistance to acids, alkalis and organic solvents, high wear resistance and resistance to a wide range of temperatures. PETG is easily machined.

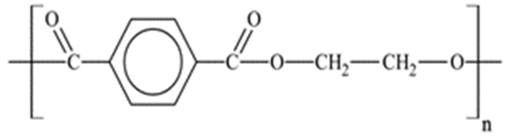


Fig. 3 Chemical formula of PETG.

The equipment and technologies of 3D printing are as follows: the extruder heats the material to the melting temperature with subsequent extrusion of the molten mass through the nozzle. The extruder itself is driven by stepper motors or servomotors that provide positioning of the print head in three planes. The movement of the extruder is controlled by production software tied to the microcontroller.

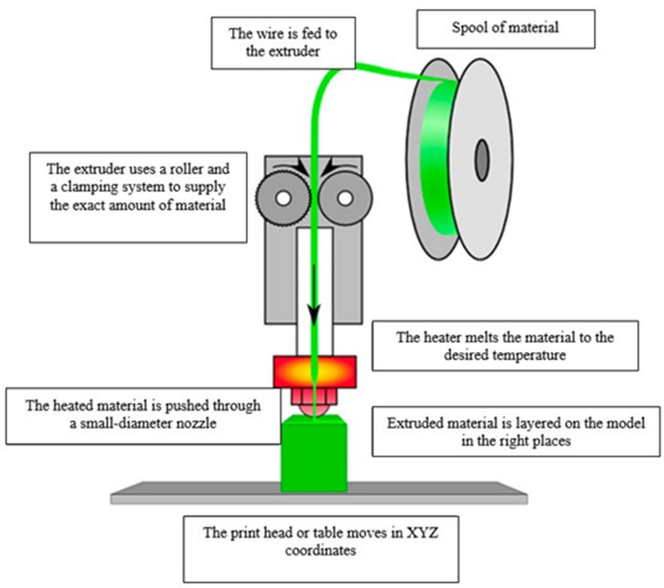


Fig. 4 Schematic of an extrusion-type 3D printer device.

The software for printing ready-made 3D models consists of three parts: interface, slicer, controller firmware.

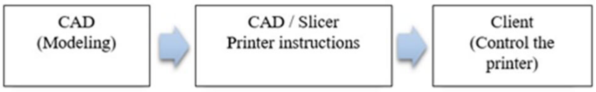


Fig. 5 Software for 3D printing.

The user interface is the program that sends the code to the 3D printer, according to which the model is printed. In this program you can set the heating temperature of the desktop and extruder, feed or remove plastic, move the print head and table in manual mode, configure the communication protocol, connect to the printer and send the model to print.

The interface sends to the 3D printer the so-called G-code - a programming language developed for CNC machines. The slicer program loads the three-dimensional model and converts it into G-code using methods to determine the optimal process modes.

3. Results

The implementation of training of a specialist in 3D-printing in the conditions of informatization of the educational and developmental process is connected with us with the creation of a thorough individual educational trajectory (IET) of professional training. The creation of R&D in the system of education of technical specialists in 3D printing is provided on the basis of individualized lifelong learning focused on the integration of different fields of knowledge.

To solve this problem, it is advisable to increase the efficiency and productivity of the educational process, reduce irrational time, minimize routine, uncreative work of students and teachers, provide an individual approach, interactivity, reliable feedback in pedagogical interaction. The formation of the IET is able to realize the potential of the latest technologies, as well as eliminate the difficulties associated with their implementation.

Improving the efficiency of training future specialists in 3D printing requires the creation of a new didactic system of teaching: updated content, organizational forms, methods and tools for teaching subjects of all cycles, taking in to account the state of informatization of the automotive industry; extensive use of computer-based educational technologies, intensification on this basis of all components of training. The use of 3D printing in universities to deepen students' professional environment in order to solve production situations will help develop creative abilities and satisfy intellectual interest among students, prepare them for the use of advanced technologies. This gives students ample opportunities to generate, develop and implement their ideas, work with combinations of materials, create amazing objects with high detail and high accuracy of modeling.

In the process of training a specialist in 3D printing IET should be combined with elements of formal education, which are provided by the selected educational program of a particular specialty, which are part of general technical training, and elements of non-formal and informal education as a logical complement to formal education. Therefore, after students choose the direction of training in 3D printing, they need to be acquainted at the expert level with an exhaustive list of necessary knowledge.

In our study, the task was to use expert assessment to outline a comprehensive and sufficient list of knowledge on the training of a specialist in 3D printing (specialization) in the system of technical specialties acquired in technical universities. This list will be useful when organizing the IET to train a specialist in 3D printing.

Based on the results of the expert evaluation, a division is constructed between the elements of formal education, which are provided by educational programs of technical specialties, and the elements of non-formal and informal education of individual choice for training a specialist in 3D printing. The list is for guidance only (table 2).

Table 2: Elements of formal, non-formal and informal education of individual choice for the training of a specialist in 3D printing in accordance with the division of knowledge

Elements of formal education	Elements of non-formal and informal education
In mathematics	
1. Algorithms for sorting data. 2. Data analysis and sorting. 3. The theory of matrices. 4. Methods of optimization and research of operations.	1. Algorithms for optimization of product manufacturing.
In chemistry	
1. Molecular structure theory. 2. Theory of relationships between atoms.	1. Influence of different environmental factors on the crystal lattice. 2. Molecular formula of the main types of plastic.
In materials science	
1. The theory of plastics. 2. Research of viscosity of substances at heating. 3. Plastic deformation.	1. Change in the volume of the finished product depending on the manufacturing temperature. 2. Influence of temperature on different types of plastic.
In machines and technologies	
1. Theory of design elements by devices. 2. Theory of design of	1. Automation of design of case products. 2. Automatic design of gears.

body parts. 3. Calculation of basic components and units. 4. Fundamentals of design in CAD. 5. Theory of machines and mechanisms and machine parts.	3. Features of software use in CAD environment. 4. The main functional defects of 3D printing.
In programming	
1. Principles of object-oriented programming. 2. Basic knowledge of CAD environment. 3. Basic knowledge of slicer programs. 4. Basics of G-code.	1. Features of 3D object modeling. 2. Features of 3D printing. 3. SolidWorks software environment. 4. Cura software environment.

During the training of a 3D printing specialist, it is necessary to make a plan for the initial training of the future specialist. We have developed a detailed content of education, which provides both basic knowledge and in-depth study of certain sections of certain disciplines.

Table 3: The basic concepts of IET training of a specialist in 3D-printing in accordance with the division of knowledge

Discipline	Topic	№	Basic concepts
Mathematics	Mathematical statistics	1	Random variable. Calculation inaccuracy
		2	Variation series. Fibonacci sequence.
		3	Probability distribution function. Random inaccuracy.
		4	Numerical characteristics of a random variable. Inaccuracy
		5	Moments of random variables. Occurrence of an inaccuracy.
		6	Laws of distribution. Golden Section
		7	Statistical hypotheses. Data analysis.
	Basics of relational algebra	8	Set theory. Set of values
		9	Relational data model. Data structure.
		10	Relational algebra operations. Data structuring.
Chemistry	Molecular chemistry	11	Crystal lattice.
		12	Interatomic bonds.
		13	Chemical formulas of the main types of plastic.
Materials science	Plastic deformation	14	Influence of temperature on different types of plastic.
		15	The volume of the product changes depending on external factors.
Machines and technologies	Technology of machines and mechanisms and details of machines	16	Calculation of basic components and units.
		17	Calculation of gears.
		18	Calculation of body parts.
		19	The main elements of the CAD environment.
		20	Design of solid objects.
Information Technology	CAD	21	SolidWorks software environment.
		22	Catia software environment.
	Slicer	23	Cura software environment.
	G-code	24	Write and edit program code
3D printing	Defects of 3D printing	25	The main functional defects of 3D printing

Using the graphoanalytical method of structuring educational material [12, p. 64] using a matrix of relationships of concepts that make up the content of training of future specialists in 3D printing (table 3), a structural and substantive model of educational material was developed (Fig. 6). built using software in Excel Visual Basic for Applications.

According to the results of research, a logical sequence of studying concepts by topics and sections of training was determined. Some topics in the sequence involve mastering concepts from different fields of knowledge. This leads to the definition of NRTI on the assimilation of material and practical tasks with the acquisition of new knowledge in various fields.

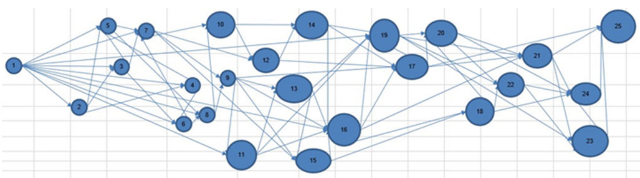


Fig. 6 Structural and substantive model of educational material.

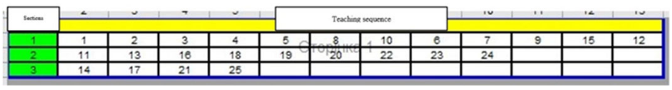


Fig. 7 The sequence of presentation of educational material.

For the formation of the future specialist in 3D printing of the full range of competencies of special importance is the knowledge of the practical implementation of the process of 3D printing.

Therefore, the last topic of the IET on mastering the material of training a specialist in 3D printing is the practical experience of using FDM technology and the results of many experimental studies in recent years, acquired and summarized by the authors of the study. This topic, which completes the process of training a specialist in 3D technology, reveals the main defects that occur in the process of 3D printing, as well as provides a description and ways to eliminate them. Due to the importance of the content of this topic, the authors provide its reference summary.

Recommendations should be taken in to account when working with appropriate equipment of additive technologies. Defects in 3D printing are quite common. They arise due to many factors, which can be divided into functional and non-functional. The first causes can be corrected by manipulating the 3D printer, even during printing. Other factors that negatively affect print quality can be corrected in the slicer settings or cannot be corrected at all.

Each type of defect occurs in almost every printing process and makes its own changes to the final product. Therefore, an experienced specialist in additive technologies, especially in 3D printing, should take them into account at the stage of modeling the object of manufacture and minimize their impact.

In general, non-functional defects are taken in to account at the design stage of the product and reduce their impact is possible only with quality training of the relevant specialist, namely:

1. Continuous training of the 3D printer operator (it is necessary to understand how the product will be printed at the modeling stage to reduce the appearance of defects);
2. Keep in mind that plastic is very sensitive to humidity, so it should be stored in a dry place and as isolated from the air (improper storage leads to loss of chemical properties of plastic and, consequently, to mechanical damage to equipment during printing, which leads not only to the appearance of product defects, but also the failure of the main components of the 3D printer);
3. The settings of the "slicer" must correspond to the plastic used in the 3D printer (each plastic manufacturer specifies the printing conditions);
4. Timely update of the software product (software is constantly improved and many settings become automatic, which improves the quality of 3D printing);
5. Keep in mind that the equipment must be equipped with a voltage rectifier and an uninterruptible power supply (when the power goes out, then the printing program fails), in 85% of cases this leads to software offset of the coordinate axes during printing, and, accordingly, to such a defect as offset layers.
6. Keep in mind that the room where the equipment is located must have stable indicators of temperature, humidity, and air conditioning (because the settings of 3D printing will change depending on the season).

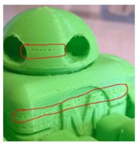
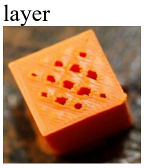
Problems with printing occur quite often. The person skilled in the art must understand what determines the appearance of defects in the model and possible ways to eliminate them. Table 5 describes the most common functional problems of 3D printing.

Table 4: The causes of defects

Type	Group	Cause
Functional	Defects of the first layer	Detachment of the first layer
		Displacement of the first
		Other defects of the first
	Defects of the upper layers	Displacement of layers
		Missing layers
		Cracks in high models
	Defects in the printing process	Holes in the top layer
		Cobweb on the model
		Undextrusion
		Re-extrusion
Not functional	Operator qualification	Not knowing the technology
		Not enough experience
	Plastic defect	In production
		Storage
	Slicer defect	False version of the software
		False settings for plastic
	Power outages	Intermittent shutdown
	Not matching the room	Temperature
		Humidity
		Air drafts

Table 5: The main functional defects of 3D printing

Functional defect	Detachment of the first layer 	Displacement of the first layer (elephant's foot) 	Displacement of layers in the model 
Cause	Deformation of the base of the part is due to the peculiarities of plastic. ABS and PLA plastic cools very quickly and this can lead to detachment of the first layer.	The base of the model is displaced due to the weight of the part, which presses on the first layer when the lower layers have not yet cooled.	The printer straps are not tight. The upper plate is not attached and moves independently of the lower plate. One of the guides on the Z axis is not perfectly flat.
Functional defect	Cobweb on the model 	Cracks on high objects 	Undextrusion 
Cause	When the printer head moves on an open surface (without extrusion), ie moves from one object to another, the plastic drains from the nozzle.	The problem most often occurs in large printers. On the upper layers, the material cools faster because the heat from the platform does not reach the required height. Due to this, the adhesion of the upper layers is lower.	The diameter of the thread may not correspond to the diameter set in the slicer. The amount of extruded material may be lower due to incorrect firmware settings. The nozzle may be clogged.

Functional defect	Missing layers 	Holes in the top layer 	Re-extrusion 
Cause	The printer was unable to squeeze enough plastic to print the missing layers. Friction can cause plastic to get stuck.	Improper cooling of the top layer. Insufficiently thick top layer.	The extrusion or flow coefficient in the slicer is too high.

Conclusion

3D printing professionals must have in-depth knowledge of engineering, programming and mathematics. The profession is related to the specialties of the future. It is for such specialists that practical recommendations are described to eliminate the influence of factors that affect the quality of the product, and it is necessary to study practical experience in this field, as such knowledge is the basis for further research.

3D printing engineers use a variety of materials, computer programs and industrial 3D printers for their work. Today, these specialists are needed in medical centers, industry, aerospace, engineering and other industries. There are few specialists because the responsibilities of a 3D printing engineer include: selecting new materials, conducting tests, using modern software to improve and adjust the parameters of the 3D printer; development of models, development of models for further printing; study of new technologies; knowledge of certification rules, requirements for 3D models and finished products; development of documentation, software debugging; selection of new equipment, training of other employees; equipment maintenance. Responsibilities depend on the workplace, but a 3D printing engineer must be a specialist who is ready to quickly master new technologies and then successfully apply them in practice. Employers have significant engineering requirements because the salaries of such specialists are high. They must have at least 3 years of practical experience, it is important to have technical knowledge of a foreign language. A 3D printing engineer must know the basics of economics and marketing, because his responsibilities include optimizing workflows to reduce the cost and speed up printing. Therefore, the knowledge gained from practical experience presented and in building for learning 3D printing engineers by the authors will be important.

References

[1] Larson, H.: *Fabricated: The New World of 3D-Printing.* Wiley. 2013. 280 p. (2013)

[2] Javaida, M., Haleema, A., Pratap Singhb, R., Sumanc, R., Rab, S.: *Role of additive manufacturing applications towards environmental sustainability*. In: Advanced Industrial and Engineering Polymer Research, 4 (4), pp. 312-322. https://doi.org/10.1016/j.aiepr.2021.07.005 (2021)

[3] Kirchheim, A., Dennig, H., Zumofen, L.: *Why Education and Training in the Field of Additive Manufacturing is a Necessity.* In: International Conference on Additive Manufacturing in Products and Applications, DOI:10.1007/978-3-319-66866-6_31 (2018)

[4] Sabrie, S.: *Additive manufacturing technology – 3D printing and design – the 4th industrial revolution*. 2020. 417p. (2020)

[5] Pandya, H. *3D printing technology: fundamentals and application.* 2021. 416 p. (2021)

[6] Smyth, Clifford T.: *Designing 3d printed things for everyday use - 3rd edition Paperback*. In: Functional Design for 3D Printing. June 26, 2017. 236p. (2017)

[7] Torta, S., Torta, J.: 3D *Printing: An Introduction Illustrated Edition*. 2018. 370p. (2018)

[8] Wallach Kloski, L., Kloski, N.: *Getting Started with 3D Printing: A Hands-on Guide to the Hardware, Software, and Services Behind the New Manufacturing Revolution Paperback* – 2016. 238p. (2016)

[9] Redwood, B., Schöffer, F., Garret, B.: The 3D Printing Handbook: Technologies, design and applications Hardcover – November 14, 2017. 304p. (2017)

[10] Sloan Cline, L. : *Fusion 360 for Makers: Design Your Own Digital Models for 3D Printing and CNC Fabrication Paperback*. – 2018. 304p. (2018)

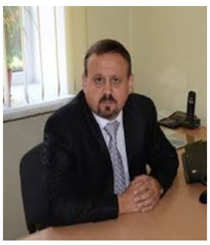
[11] Tulashvili, Y., Marchuk, V., Lukianchuk, I.: *Additive IT technologies for education specialists in engineering specialties.* In: Modern education, training and upbringing: collective monograph / Abdullayev A., Rebar I., – etc. - International Science Group. – Boston : Primedia eLaunch, 2021. 594. Available at: DOI - 10.46299/ISG.2021.MONO.PED.I (2021)

[12] Asherov, A., Malevanaya, V.: *Methods and models of teaching students of computer specialties in ergonomic expertise of the working environment.* Kharkov: publishing house "NTMT", 2009. - 151. P. 64. http://library.uipa.edu.ua/images/data/monografies/asherov_metod.pdf (2009)

Iurii Lukianchuk in 2012 received the scientific degree PhD of technical sciences from the Lutsk National Technical University. From 2012 to 2016, he worked at the Lutsk National Technical University at the Department of Instrumentation, from 2020 to the present, as an associate professor of the Department of Computer Sciences. Scientific interests are aimed at the development of software for modeling technological processes, research of innovative technologies in education and production, design, development and maintenance of software. Published more than 60 scientific works in international journals.

Yurii Tulashvili in 1997 he received the scientific degree PhD of Technical Sciences at the Lutsk Industrial Institute, Doctor of Pedagogical Sciences since 2013. Since 1987 has been working at the Lutsk National Technical University, currently as a professor of the Department of Computer Sciences. Scientific interests are aimed on research the effectiveness of the use of computer technologies in education, science and production; on mathematical modeling of digital systems; on development of digital platforms in the urban economy. He has published a number of scientific works in international journals, is the author of 4 monographs and 5 textbooks on computer technology , is a member of the editorial board of the journal "Science bulletin VSU".

Volodymyr Podolyak in 1999 received the scientific degree PhD of technical sciences from the Lutsk National Technical University. Since 1999, he has been working at the Lutsk National Technical University, currently as an associate professor of the Department of Computer Sciences. Scientific interests are focused on the development and operation of information systems and research of innovative technologies in education. Published more than 80 scientific works in international journals.



Roman Horbatiuk, Doctor of Pedagogical Sciences. Head of the mechanical engineering and transport department, Ternopil Volodymyr Hnatiuk National Pedagogical University (Ternopil, Ukraine). Since 1990 he has been working at Ternopil Volodymyr Hnatiuk National Pedagogical University, currently, as head of the Mechanical Engineering and Transport Department. Research interests: improving the professional training of the future teachers of professional education, innovative technologies introduction into the educational process of higher education institutions. He has published a number of scientific papers in international journals. He is a member of the editorial boards of journals «Ukrainian Journal of Educational Studies and Information Technology», «Professional education: methodology, theory and technologies».

Vasyl Kovalchuk studied at Yuri Fedkovych Chernivtsi State University in 1993-1998 and got specialist degree in Professional education. In 2005 he gained candidate degree in Pedagogical Sciences. In 2014 defended doctoral dissertation "Theoretical and methodological principles of developing pedagogical skills of vocational schools professional training masters in postgraduate education" and became Doctor of Pedagogical Sciences. In 2018 he became a professor of the Department of Teaching Methods and Management of Educational Institutions of the National University of Life and Environmental Sciences of Ukraine. Since 2018 he has been working as the Head of the Department of Vocational Education and Technologies of Agricultural Production of Oleksandr Dovzhenko Hlukhiv National Pedagogical University. He is the head of the School of Pedagogical Skills. His scientific interests include professional and higher education development, introducing innovative teaching technologies in the educational process, teachers' pedagogical skills development, introducing digital technologies in the educational process, emotional intelligence development, leadership.

Serhii Bazyl, received higher pedagogical education at Hlukhiv State Pedagogical University in 2003. In 2021, he received a Ph.D. in 015 Professional Education (specializations). Since 2003, he has been working as a teacher of professional computer disciplines. Since 2011 he has been the Head of the Laboratory of Computer Systems and Networks of the Separate Structural Subdivision "Shostka Vocational College named after Ivan Kozhedub of Sumy State University". The range of his scientific interests includes the introduction and application of Computer-Integrated Systems and Digital technologies in the educational process of institutions of professional pre-higher and higher education.