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RESEARCH ARTICLE

PECULIARITIES OF THE INTRODUCTION OF ADDITIVE TECHNOLOGIES IN THE EDUCATIONAL DESIGN PROGRAMME

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Abstract. *The introduction of additive technologies into the educational process of design opens up new horizons for improving the training of new specialists after graduation. Technologies such as 3D printing and modeling can significantly expand the opportunities for training young specialists in the field of industrial design. The article discusses the key aspects of integrating additive technologies into design curricula, including technical and methodological approaches. Particular attention is paid to practical classes that help develop students' design thinking, design and prototyping skills. The advantages of additive technologies, such as waste reduction, the ability to create complex geometries and resource savings, are considered. Examples of the successful use of 3D printing in educational institutions, such as the laboratory at KazGASA, are given and real projects made using this technology are demonstrated, which confirms its effectiveness in industrial design, and the benefits associated with their use in the educational environment are analyzed. In conclusion, it is concluded that additive technologies not only enrich the educational process, but also prepare students for the modern requirements of the labor market, where the skills of working with the latest technologies are becoming increasingly in demand. In conclusion, the article highlights the need for further research and integration of additive technologies into educational programs to prepare highly qualified specialists capable of solving problems corresponding to the challenges of the future.*

Keywords: *additive technologies, 3D modeling, 3D printing, practical classes, education, impact on learning.*

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ҒЫЛЫМИ МАҚАЛА

БІЛІМ БЕРУ ДИЗАЙН БАҒДАРЛАМАСЫНА АДДИТИВТІ ТЕХНОЛОГИЯЛАРДЫ ЕНГІЗУ ЕРЕКШЕЛІКТЕРІ

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Аңдатпа. *Дизайнның білім беру процесіне аддитивті технологияларды енгізу бітіргеннен кейін жаңа мамандарды даярлауды жақсарту үшін жаңа көкжиектер ашады. 3D басып шығару және модельдеу сияқты технологиялар өнеркәсіптік дизайн саласындағы жас мамандарды даярлау мүмкіндіктерін едәуір кеңейтуге мүмкіндік береді. Мақалада техникалық және әдістемелік тәсілдерді қоса алғанда, аддитивті технологияларды дизайнерлік оқу бағдарламаларына біріктірудің негізгі аспектілері қарастырылады. Студенттердің дизайнерлік ойлау, жобалау және прототиптеу дағдыларын дамытуға ықпал ететін практикалық сабақтарға ерекше назар аударылады. Қалдықтарды азайту, күрделі Геометрияларды құру мүмкіндігі және ресурстарды үнемдеу сияқты аддитивті технологиялардың артықшылықтары қарастырылады. ҚазБСҚА жанындағы зертхана сияқты білім беру мекемелерінде 3D-басып шығаруды табысты пайдалану мысалдары келтіріледі және осы технологияны пайдалана отырып орындалған нақты жобалар көрсетіледі, бұл оның өнеркәсіптік дизайндағы тиімділігін растайды, сондай-ақ оларды білім беру ортасында қолдануға байланысты артықшылықтар талданады. Қорытындылай келе, аддитивті технологиялар оқу процесін байытып қана қоймайды, сонымен қатар студенттерді жаңа технологиялармен жұмыс істеу дағдылары барған сайын сұранысқа ие болатын еңбек нарығының заманауи талаптарына дайындайды деген қорытындыға келеді. Қорытындылай келе, мақала болашақтың сын-қатерлеріне сәйкес келетін міндеттерді шеше алатын жоғары білікті мамандарды даярлау үшін қосымша технологияларды одан әрі зерттеу және білім беру бағдарламаларына біріктіру қажеттілігін көрсетеді.*

Түйін сөздер: *аддитивті технологиялар, 3D модельдеу, 3D басып шығару, практикалық сабақтар, білім беру, оқытуға әсер ету.*

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НАУЧНАЯ СТАТЬЯ

ОСОБЕННОСТИ ВНЕДРЕНИЯ АДДИТИВНЫХ ТЕХНОЛОГИЙ В ОБРАЗОВАТЕЛЬНУЮ ДИЗАЙН-ПРОГРАММУ

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Аннотация. *Внедрение аддитивных технологий в образовательный процесс дизайна открывает новые горизонты для улучшения подготовки новых специалистов после выпуска. Такие технологии, как 3D-печать и моделирование, позволяют значительно расширить возможности для подготовки молодых специалистов в области промышленного дизайна. В статье рассматриваются ключевые аспекты интеграции аддитивных технологий в учебные программы по дизайну, включая технические и методологические подходы. Особое внимание уделяется практическим занятиям, которые способствуют развитию у студентов навыков дизайн-мышления, проектирования и прототипирования. Рассматриваются преимущества аддитивных технологий, таких как снижение отходов, возможность создания сложных геометрий и экономия ресурсов. Приводятся примеры успешного использования 3D-печати в образовательных учреждениях, таких как лаборатория при КазГАСА, и демонстрируются реальные проекты, выполненные с использованием данной технологии, что подтверждает её эффективность в промышленном дизайне, а также анализируются преимущества, связанные с их применением в образовательной среде. В заключение делается вывод о том, что аддитивные технологии не только обогащают учебный процесс, но и готовят студентов к современным требованиям рынка труда, где навыки работы с новейшими технологиями становятся все более востребованными. В заключении, статья подчеркивает необходимость дальнейшего исследования и интеграции аддитивных технологий в образовательные программы для подготовки высококвалифицированных специалистов, способных решать задачи, соответствующие вызовам будущего.*

Ключевые слова:. *аддитивные технологии, 3D-моделирование, 3D-печать, практические занятия, образование, влияние на обучение.*

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

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Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

Modern tasks that appear in the market of consumption and production require more and more technically complex objects in a short time. In order to be in a leading position in the world, it is necessary to introduce new ideas for the world of design and production as quickly as possible. Such needs are caused by reforms in the educational system in the training of specialists for new working conditions and the development of innovative design thinking. One of these emerging technologies is additive manufacturing, which is one of the best solutions for the speedy implementation of new ideas.

Today, additive technologies are often used in various spheres of our life, such as: medicine, construction, outer space, renewable energy sources, in the food industry and others (**Armashova-Telnik et al., 2020**). They help in the creation of three-dimensional objects, models, and various prototypes. Its principle of operation is based on the use of layer-by-layer superimposition of material, such as: metal, plastic, ceramics, paper, composites, polymer.

2 LITERATURE REVIEW

Usually, the manufacture of one complex part may require a lengthy technological process that includes many stages. Often, it requires a number of certain equipment, labor costs, time and finances. Thus, additive technologies make it possible to replace not only an entire production line with a single unit, significantly reducing the time for manufacturing complex parts, but also to save resources, especially metal.

M.A. Zlenko, A.A. Popovich and I.N. Mutylina in their work "Additive Technologies in Mechanical Engineering" consider various aspects of the additive technologies application in this industry. They analyze the advantages and disadvantages of these technologies, as well as their impact on production processes and end products. Thus, by describing a simple sequence of additive manufacturing (**Figure 1**).

This methodology ensures that students not only grasp theoretical concepts but also acquire practical expertise, making them industry-ready upon graduation. In the work of M.A. Litvinova, there is an emphasis on the use of additive technologies in the learning process. Research is being carried out within the framework of the specialty in engineering graphics, which ultimately confirms the effectiveness of using 3D printers. According to the experiment, these technologies increase motivation to study, improve academic performance and develop artistic and design thinking (**Litvinova, 2023**). Similarly, **Vishnevskaya et al. (2019)** explore the environmental benefits of 3D printing, noting its potential to minimize production waste and support sustainable design practices.

The literature emphasizes the need for structural integration of additive technologies into design curricula. While numerous studies highlight its benefits, there is a research gap regarding optimal learning strategies that would maximize its educational impact.

Figure 1 – General diagram of the process of creating a 3D model

The popularization of 3D printers began relatively recently, 17 years ago, after the global financial crisis in 2008. After the economic recovery, entrepreneurs began to actively increase the purchase of 3D machines, thereby reducing the cost of equipment. Because they understood that the future belongs to additive technologies (**Makarov, 2018**). Thus, over the past decade, 3D printing has begun to be actively implemented in various spheres of life. At present, they are actively used in industrial design. They allow you to create complex and unique projects that contribute to prompt work in design. The integration of such technologies into the educational process in the field of industrial design will contribute to the opening of new opportunities for students and teachers, developing their creative and practical skills. If earlier 3D printers were bulky and expensive machines that were available only to large enterprises, now they have significantly decreased in size and price. Modern printers are able to fit on a desktop, and their cost has become several times cheaper, which has expanded the range of potential users, especially for the education sector.

There are many types of 3D printers that work on different technologies, use different printing methods, and use a variety of materials. The most common type of printer is Fused deposition modeling (FDM) (**Figure 2**).

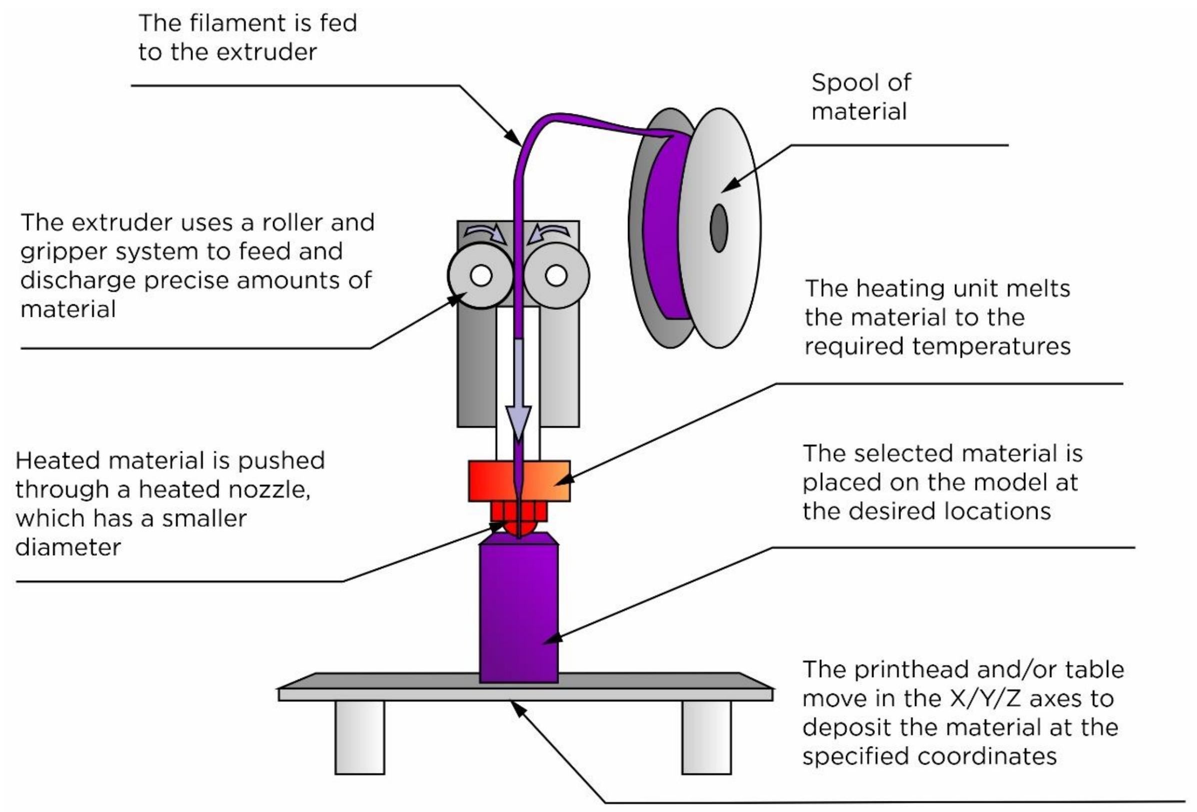

Figure 2 - Fused deposition modeling (FDM) method

The principle of the technology is that when the extrusion nozzle and the plastic filament on the spool are heated, the filament is melted, after which it goes in a given sequential trajectory to the surface of the platform in the form of thin filaments, creating a three-dimensional object (**Figure 3**) (**Yakushev, 2018**). The extruder has a 3-axis system that can be moved in the direction of X, Y, Z. When the layer is complete, the platform is lowered down (or, in some printer models, the extruder is lifted up) and a new layer is applied to the already hardened one. This process, based on deposition deposition technology, is repeated until the model is fully printed (**FDM technology. How it works, 2019**). The layer-by-layer deposition process begins with the creation of a 3D computer model. The software downloads the model in STL format, then analyzes it across all cross-sections and calculates the layer-by-layer deposition algorithm (**Yakushev, 2018**).

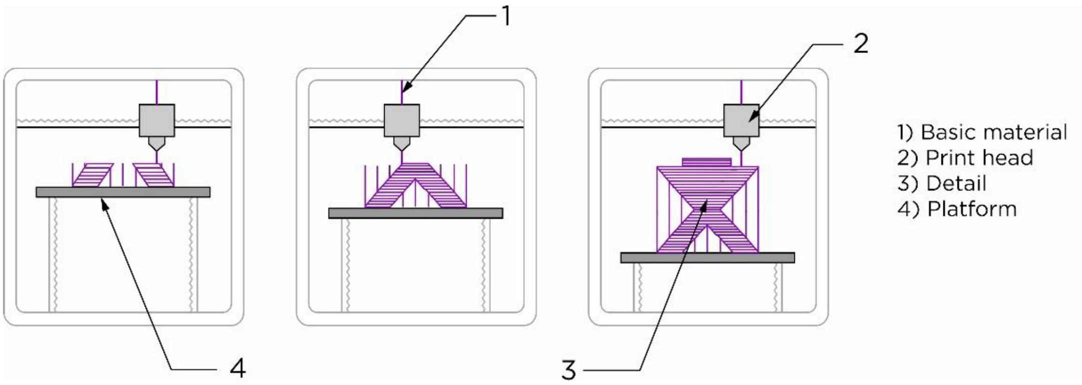

Figure 3 – Diagram of the FDM printing process

Additive technologies have a number of advantages:

– The predominance of digital production over traditional production. Since additive manufacturing minimizes the human factor for errors, allows you to create an innovative and unique product, and has a relatively low cost of finished products. The difference between traditional and additive manufacturing can be seen in the diagram (**Figure 4**).

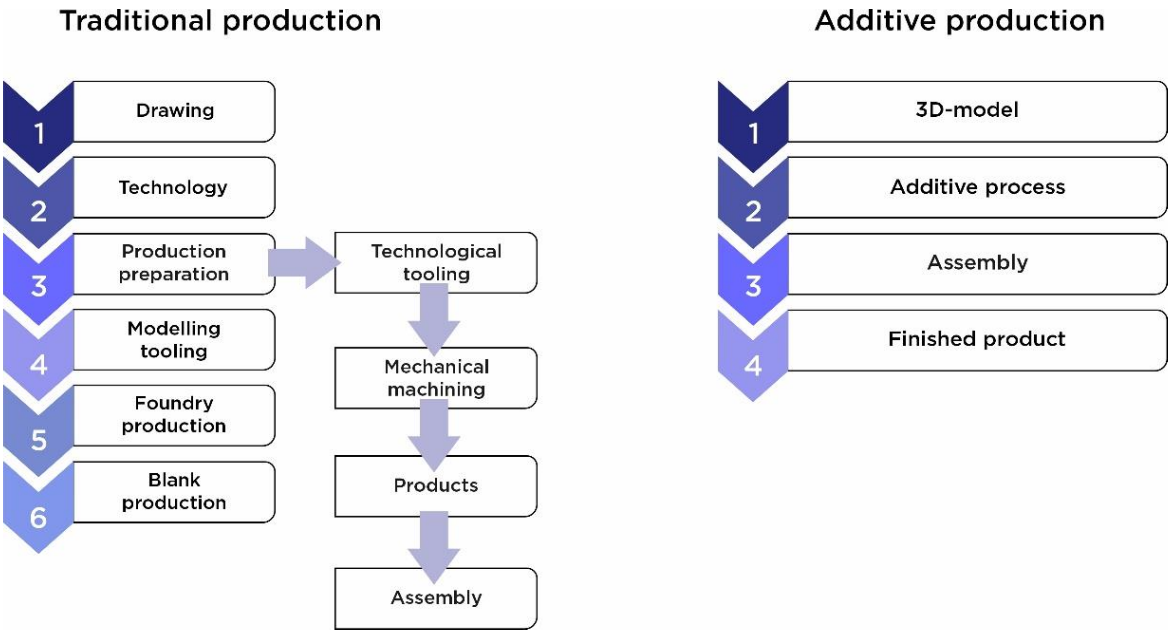

Figure 4 – Schematic difference between traditional and additive design

– Reducing waste. Since the material is added only where it is needed, additive technologies significantly reduce the amount of waste compared to the traditional approach, where excess material is often removed and discarded. For the environmental situation in the world, this point is of great importance. Production processes and their material surpluses have a detrimental effect on all aspects of human life, and the reduction of this waste has a positive effect on nature. Environmental issues contribute to the development of sustainable design, which is implemented not only in all workshops, but also in social and political processes (**Vishnevskaya et al., 2018**).

– Ability to create complex geometries. Unlike traditional manufacturing methods such as casting or milling, additive manufacturing creates objects by adding material layer by layer. This allows for the creation of complex geometries that are impossible or difficult to produce by other methods.

– Flexibility in design. Additive manufacturing gives designers and engineers a lot of freedom to create unique and complex designs. This is especially useful in fields such as architecture, medicine, and jewelry.

– Rapid prototyping. Additive technologies allow for rapid prototyping and testing, which speeds up the process of developing and introducing new products. This is especially important in competitive industries where speed to market is critical (**Kolesnikov et al., 2017**). One of the most successful areas of application of additive technologies is medicine. In particular, it is actively used in the training of neurosurgeons, traumatologists and orthopedists, where it is necessary to hone the skills of manual therapy. The development of 3D technologies allows doctors to reduce the time of surgery, tissue structures, surgical instruments and create high-precision implants suitable for each patient. In neurosurgery, the technology is more often used to treat patients with skull defects and various spinal pathologies. In 2021, I. S. Brattsev and his colleagues studied the results of the treatment of skull defects, which involved 50 patients. They compared the two approaches, dividing the patients into two groups: the first was 3D printing individual mock-ups and the second was traditional modeling. As a result of the treatment, the first group had less time to operate, the implants were more accurate, and the risk of complications was reduced. The active use of these technologies proves their effectiveness and the further development of innovative approaches in medicine (**Yarikov et al., 2022**).

– Personalization and customization. The ability to create custom products makes additive manufacturing ideal for the production of medical implants, prostheses, and other personalized products. These methods are particularly suitable for optics design, where personalization for the selection of glasses is the main aspect. Compared to traditional eyewear manufacturing, 3D modeling and 3D printing allow the model to be adapted to individual human parameters (width, thickness, weight, position of the frame and nose pads). It also helps to optimize the operation of optical products in production and introduce new capabilities of microelectronics and microoptics (**Ivanov, 2023**).

– Cost-effectiveness for small batches. For the production of small batches of products, additive technologies can be more cost-effective than traditional methods, since they do not require the creation of expensive molds and tooling (**Yuliya, 2022**). In recent years, higher education institutions have been experiencing changes in approaches to the evaluation of term papers and theses in the field of industrial design. Traditional design includes manual production of models, which is the basis for the professional training of future specialists. Prototyping is studied from the first lessons and throughout almost all years of study (**Knizhnyak & Pilyugin, 2019**). However, thanks to the introduction of new technologies, the layouts can be improved, and students will receive a ready-made, or maybe working product, which can be promoted on the market in the future.

A big plus is that students can easily transfer electronic files with 3D models on the university's educational portal and conduct discussions remotely. This technology can be used not only by students, but also by teachers, thereby improving their qualifications and teaching methods (**Kolpakova, 2024**).

3 MATERIALS AND METHODS

To successfully implement additive technologies in design education, a structured approach to practical learning is needed. The organization of practical classes plays a key role in the integration of additive technologies (**Table 1**). They allow students to receive not only new theoretical knowledge, but also to apply it in practice. Such methods make it possible to improve the quality of training and the level of training of specialists.

Modern education is increasingly focusing on practical learning, and this is no coincidence. Theoretical knowledge is the foundation, but it is practical training that turns it into a solid and reliable building, ready to withstand the trials of the real world. Let's figure out why practical classes are not just an addition to the educational process, but its integral and, perhaps, the most important part (**Dresvyannikov et al., 2018**).

Table 1
Example of the organization of practical classes

	Stages and content of lessons	Practical task
1	*Introduction to 3D Printing* Introduction to Design Principles.	-
2	*Theoretical foundations.* The first classes can be devoted to familiarizing students with the theoretical foundations of 3D modeling and printing. In the introductory lesson, students learn about different types of 3D printers, what programs are best used to work with for prototyping a model, and what materials can be used for printing.	Students must complete several versions of sketches.
3	*Design and modeling.* At this stage, students learn more about the design process. They learn techniques for creating complex shapes and functional design objects in a variety of object modeling software. Here they will study the construction of three-dimensional models on a PC, work in 3D programs (Blender, 3DsMax, Sketch Up, Shapr, etc.) and visualization of the idea.	In the practical task, the result is the creation of a simple 3D model and the creation of a visualization in the selected program.
4	*Preparation for 3D printing.* Students learn how to work in special programs and adjust print settings. Choosing the right material for your project.	Self-preparation of the model for printing.
5	*Printing process.* Students learn to create prototypes of their own projects and test them for compliance with specified requirements.	Monitor the printing process and solve problems.
6	*Post-processing of the product.* At this stage, having received the finished product, the student proceeds to its post-processing (sanding, painting, etc.).	Testing the object for use in finalizing your layout.
7	*Analysis and evaluation.* Evaluate print quality and its effectiveness in creating a layout.	Presentation of finished projects and discussion of their application

This methodology ensures that students not only grasp theoretical concepts but also acquire practical expertise, making them industry-ready upon graduation.

First and foremost, students develop their design and prototyping skills. They gain practical experience that allows them to better understand the process of manufacturing products and conduct an analytical analysis of their product.

Development of design and prototyping skills: from an abstract idea to a real product. Theory explains principles, but practice forms the ability to apply them. Practical classes allow students to go through the entire cycle of creating a product - from the idea to the finished prototype. This is not just assembling a model according to the instructions; This is immersion in the design process, taking into account technical limitations, finding optimal solutions, dealing with unforeseen difficulties and, finally, the satisfaction of creating something with your own hands. In the process of work, students master various software tools (3DsMax, SolidWorks, Blender and others, depending on the specialty), learn to work with various materials, analyze the results and make adjustments to the project. This forms critical thinking, the ability to make decisions in conditions of uncertainty and, importantly, develops teamwork skills, especially when implementing group projects (**Zhuykova & Akhmedzyanov, 2019**).

Increasing motivation: interest as an engine of progress. Passive perception of information often leads to a decrease in motivation. Practical classes, on the contrary, turn learning into an exciting process. Students see the results of their work, receive immediate feedback, and feel involved in creating something new. This evokes positive emotions, builds self-confidence and stimulates further study of the subject. The student's interest directly affects the depth of mastering the material, so practical classes contribute not only to the development of skills, but also to a deeper understanding of the theoretical foundations.

Touching upon the issue of improving the effectiveness of learning, we can give an example of the experience of 2nd year students of the Pedagogical Institute of VlGU. As part of the discipline "3D modeling in technical creativity", students performed the task of creating a map-layout "Hero Cities of the Great Patriotic War", studying and applying 3D technologies. During the implementation of this project task, students mastered the skills of 3D graphics, learned how to create three-dimensional models and work in specialized programs for 3D printing (**Khrustaleva et al., 2022**).

Preparation for real working conditions: a bridge between the university and the professional environment. The modern labor market places high demands on specialists. Knowledge of theory is only part of success. Employers value candidates who have practical experience, are able to work with modern technologies and quickly adapt to new conditions. Practical classes significantly increase the competitiveness of graduates. They learn to work in a team, solve problems in a short time, present the results of their work and interact effectively with managers. This experience is invaluable and greatly facilitates the process of adaptation to a new workplace.

Practical classes are not just an additional activity, but an integral part of quality education, providing not only the development of practical skills, but also an increase in motivation, preparation for real working conditions and, ultimately, a successful career of graduates. Investing in practical training is an investment in the future, an investment in high-class professionals.

4 RESULTS AND DISCUSSION

The examples of successful use of 3D printing: 3D printing activities are beginning to gain momentum in the educational system. In particular, we can mention the laboratory at KazGASA University, which was opened in 2023 (**Figure 5**). It contains laser, milling, vacuum machines, 3D-Scanner, FDM 3D printer and other working tools. The lab has been successfully favoured by architecture students and industrial designers.

Figure 5 – Laboratory at KazGASA (academic pedagogical internship, photo by the author)

This workshop is an integral element of the technological support of the process of training designers. In the workshop, students acquire skills of layout modelling and plastic work on surfaces (plastic, metal, wood). The application of modern technologies in practice plays an important role in the professional status of graduates not only in domestic universities, but also abroad. A large room on the basement floor of the university has been allocated for the layout workshop, which can be accessed by pre-arranging a visit with the head of the laboratory, who helps students in realising their ideas for course projects. The University's Layout Workshop assists in organising the university events, exhibitions and project presentations, as well as enhancing the teaching facilities.

Such modern approaches to teaching visually demonstrate to students the phenomena and objects studied, which will help them in the future to work with the production process.

The next example is the work of Aziz Abdulmazhitov, a graduate of the International Education Corporation KazGASA, the founder of the company ART GUILD. This company was founded in 2012, which develops and produces non-standard products from metal, wood, plastic for interiors and public spaces. One of his works is the production of cachepots for Mega centre (**Figure 6**). The main body is made of steel and the white flower-lights are 3D-printed. To be more efficient, the framework of the lights was printed simultaneously on 8 printers, as each flower takes about 15 hours to print. This work clearly demonstrates the effectiveness of 3D technology. It made it possible to eliminate human errors and optimise the production process for the delivery of the object.

Figure 6 – Part of the project using a 3D printer by ART GUILD founder A. Aziz, a graduate of International Education Corporation KazGASA. Source: https://goo-gl.com/yzm

Another striking example is Sofia Mun, a graduate of KazGASA, specialising in Industrial Design. She is one of the best students of the university and an example for many of her fellow students. Her work has always been characterised by quality elaboration of all details and creation of working prototypes and models for coursework. After completing her Master's degree at La Sapienza University of Rome, she started her own production of lighting fixtures under the name ‘Lumi Lampa’ (**Figure 7**).

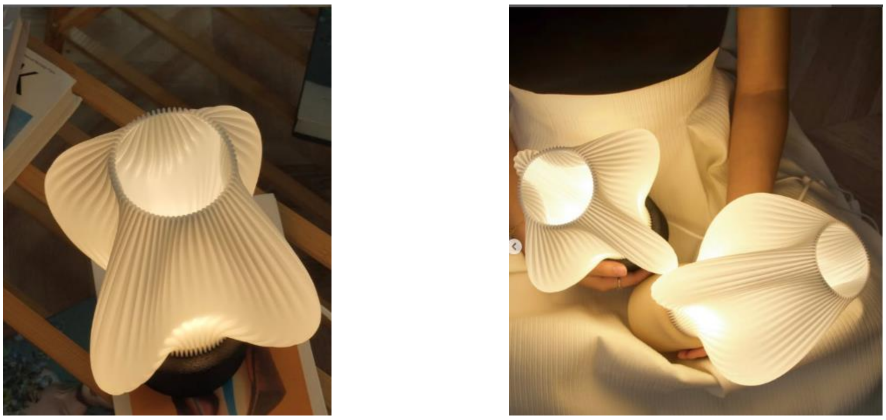

Figure 7 – author-developed lamps “Tulip”; additively created by Sofia Mun, a graduate of the educational program “Industrial Design”, International Educaton Corporation KazGASA). Source: http://surl.li/qhktsi

These successful graduate projects highlight the transformative impact of 3D printing on career development. The integration of 3D printed components in Aziz's projects into large-scale interior design projects and Sofia's application in customized lighting solutions serve as examples of how design students can use these technologies to succeed in entrepreneurship.

5 CONCLUSIONS

During the research, it can be found that the use of 3D technology in the educational process for designers has significant advantages such as: improving the perception of information, stimulating creativity and developing visualisation skills. Also, we have clearly seen how 3D printing is already applied in real production. The increase in innovative tools is directly related to design education. The study of 3D design is especially important for industrial design professionals. Since they create a product directly for people and prototyping is the most important step before production. However, their effectiveness in the educational process is still under investigation and requires continuous research in this matter.

It is becoming obvious that such a rapid pace of additive technologies development inevitably requires their integration into educational programmes in design. By providing students the opportunity to work with modern equipment, the university prepares a new generation of innovators and creators capable of solving complex technology problems (Lipnitsky & Pilgun, 2018).

In general, 3D-technologies can be effectively used in the educational process for designers under certain conditions and recommendations. It is advisable to apply them in the practical part, regardless of the classes, in competitive events and so on. Therefore, the introduction of 3D-technologies into educational programmes contributes to the training of highly qualified specialists ready for the challenges and opportunities of the future.

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