

THE TRANSFORMATIVE ROLE OF ADDITIVE TECHNOLOGIES IN MODERN EDUCATION

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Additive technologies, known as 3D printing, are revolutionizing education by turning abstract concepts into tangible learning experiences. Most domestic and foreign studies examine additive technologies in detail from a technical point of view. In these studies, the authors' attention is usually focused on the study of new materials available for additive manufacturing, their behavior under various loads and in various environments, methods of organizing production using additive manufacturing installations, etc. Research works are appearing on 4D technology, which will create a new generation of self-changing products capable of responding to changes in the environment, including temperature and humidity. The conducted analysis showed that additive technologies are practically not considered by authors from the point of view of their use in the educational process, regardless of the specific level of education. The conceptual apparatus devoted to the use of additive technologies in education has not been formed in its final form. Modern challenges facing science and technology necessitate the design of increasingly complex technical objects in a short time. Therefore, one of the most important tasks is the use of new (additive) technologies. Additive technologies provide students with professional competencies aimed at the ability to create and process three-dimensional objects, set up and maintain installations for additive production, create models, prototypes and objects using additive technologies. The scope of CAD use is growing dynamically and if until now the main areas of implementation were various branches of mechanical engineering and industrial systems, now they are used in construction, medical and biological problems, in particular, for the design of endoprostheses. Students print geometric figures, models of various parts and simple mechanisms, combining theory with practice. Creating copies of artifacts and sculptures deepens the understanding of culture. Prototyping and anatomical models improve design skills. Large-scale models simplify the study of spatial thinking. Practical work with 3D printers prepares students for professionalism in production.

Interactive projects stimulate motivation and creativity, initiate critical thinking, simplify problem solving through iterative design processes, and ensure the availability of practical implementation. Personalized tools take into account the different needs of students. In addition, the use of additive technologies increases interdisciplinarity in the educational process - combining natural sciences, technology, engineering, and mathematics with the humanities and arts.

The advantages of additive technologies when used in the educational process include: the ability to obtain finished prototypes of products within a single lesson, demonstration of some features of a specific technology, safety of the product manufacturing process, the ability to develop and print auxiliary equipment for other subjects/disciplines, and expansion of students' capabilities when working on their own projects. Additive technologies in education should be considered in two main aspects: - as a set of principles, methods, and means of creating a three-dimensional object by constructing it layer by layer in the working area of an additive manufacturing installation, which directly forms the basis of the concept of "additive technologies" (a set of technical means consisting of engineering design technologies, 3D modeling, programs for preparing g-code (slicers), and an additive manufacturing installation); - an area of knowledge related to the patterns, principles, and organization of the educational process for its effective construction and implementation.

Future trends will allow for a reduction in the cost of training, as cheaper printers and open materials will make the technology more accessible, and hybrid learning – the use of cloud platforms, allows for remote design and printing. The integration of artificial intelligence and augmented reality allows for the creation of smart algorithms that optimize design, and augmented reality makes training interactive.

Additive technologies are changing education, making it exciting and inclusive. At the present stage, additive technologies are increasingly being implemented and distributed in various areas of production, which requires, first of all, the education system to prepare highly qualified personnel.

The advantages of additive technologies when used in the educational process include: the ability to obtain finished prototypes of products within one lesson, demonstration of some features of Industry 4.0, safety of the product manufacturing process, the ability to develop and print auxiliary equipment for other subjects/disciplines, and expansion of students' capabilities when working on their own projects. At the same time, there are a number of problems associated with the organization of the educational process for students to master a number of disciplines, starting from the general education level, which requires the development of methodological approaches to the organization and implementation of educational classes using additive technologies, methodological recommendations for the use of appropriate educational equipment, hardware and software.

In conclusion, additive technologies represent a paradigm shift in education, offering transformative opportunities for skill development, interdisciplinary engagement, and practical implementation. Addressing the current research gap and formalizing their pedagogical framework will be crucial for maximizing their impact across educational systems.