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THE APPLICATION OF SPATIAL MODELING AND 3D TECHNOLOGIES IN ENGINEERING GRAPHICS EDUCATION

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Abstract: This article examines the didactic possibilities of applying spatial modeling and 3D technologies in engineering graphics education. The role of three-dimensional modeling in developing students' spatial thinking, technical imagination, and constructive reasoning is analyzed. The effectiveness of integrating modern 3D modeling software such as AutoCAD, SolidWorks, and Kompas-3D into the educational process is substantiated. The study highlights that the use of 3D technologies enhances visualization, integrates theoretical knowledge with practical skills, and increases students' cognitive engagement. The research findings confirm the importance of interactive and visual teaching methods in forming the professional competencies of future engineers.
Keywords: engineering graphics, spatial modeling, 3D technologies, spatial thinking, three-dimensional models, graphic software, visualization, technical education.

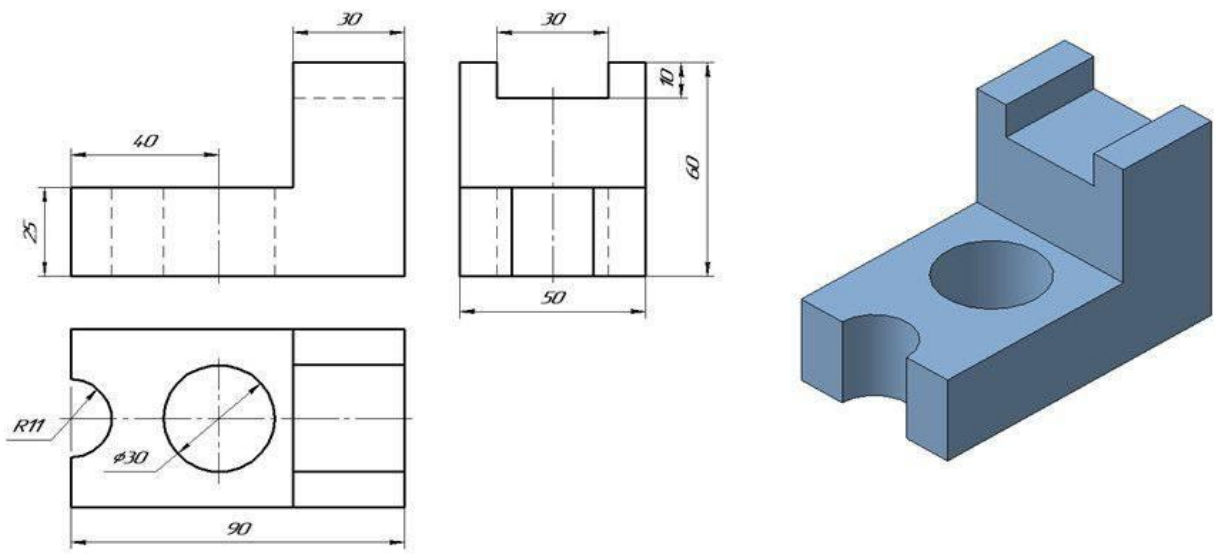
In the context of modern engineering education, the rapid development of digital technologies necessitates a fundamental renewal of educational content, teaching methods, and pedagogical approaches. In particular, the transition from traditional two-dimensional drawings to three-dimensional digital modeling in engineering graphics has become one of the key directions of global educational trends. International experience demonstrates that the integration of spatial modeling and 3D technologies into the educational process effectively contributes to the development of students' spatial thinking, technical reasoning, and practical engineering competencies. Engineering graphics occupies a central position within the system of engineering disciplines, as it forms essential skills related to reading technical documentation, creating drawings, and analyzing constructive solutions. However, pedagogical practice indicates that the perception of complex spatial forms based solely on two-dimensional graphical representations presents significant challenges for many students. Therefore, the use of 3D modeling technologies in the educational process is increasingly emerging as a necessary pedagogical requirement.

In recent years, the widespread use of modern graphic software such as AutoCAD, SolidWorks, Fusion 360, and Kompas-3D has elevated engineering graphics education to a qualitatively new level. Through these software tools, students gain the opportunity not only to create three-dimensional models of parts and assemblies but also to conduct in-depth analyses of their geometric, functional, and constructive characteristics. This approach ensures a strong integration between theoretical knowledge and practical activity. Numerous international studies have scientifically substantiated that three-dimensional modeling in engineering graphics education serves as an effective tool for developing students' spatial thinking. Several researchers emphasize that limiting engineering graphics instruction to traditional two-dimensional drawings leads to difficulties in students' ability to visualize geometric forms in three-dimensional space. In this regard, the implementation of 3D modeling technologies has been found to simplify the perception of graphic information and significantly enhance the comprehensibility of instructional materials.

Classes organized on the basis of software tools such as AutoCAD, SolidWorks, Fusion 360, and Kompas-3D have been reported to enhance students' learning motivation and to foster the development of independent thinking and engineering problem-solving skills. Some authors have demonstrated that a visualized learning environment created through 3D technologies facilitates faster comprehension of abstract concepts. Moreover, the scientific literature indicates that the application of spatial modeling enables students to achieve higher performance in reading technical drawings, identifying relationships between projections, and analyzing assemblies. At the same time, several studies note that when the implementation of 3D technologies is not methodologically well planned, the expected educational outcomes may not be achieved. This highlights the necessity of introducing these technologies on a sound pedagogical basis through a systematic instructional approach.

International research emphasizes that learning activities based on 3D technologies demonstrate high effectiveness in developing students' learning motivation, independent reasoning, and decision-making skills in problem-based situations. From this perspective, the methodologically grounded application of spatial modeling in engineering graphics education is considered a relevant scientific and pedagogical issue.

This article aims to determine the impact of spatial modeling and 3D technologies on the effectiveness of engineering graphics education by employing a comprehensive methodological approach. Both theoretical and empirical research methods were used. At the theoretical stage, scientific and pedagogical literature related to engineering graphics, spatial thinking, and 3D modeling was analyzed, existing approaches were systematized, and general conclusions were drawn. Based on this analysis, the conceptual foundations of the study were formulated. Within the framework of empirical methods, pedagogical observation, comparison, and analytical methods were applied. The outcomes of engineering graphics classes conducted using traditional teaching methods were compared with those organized on the basis of 3D technologies. Changes in students' spatial thinking, drawing interpretation skills, and abilities to analyze three-dimensional models were examined.



In order to demonstrate the possibilities of spatial modeling in engineering graphics classes, the following part was selected as an illustrative example. The part is represented by three principal orthographic projections (front, top, and side views) as well as a three-dimensional (3D) model. According to the drawings, the overall dimensions of the part are 90 mm in length, 60 mm in height, and 50 mm in width. The part includes a cylindrical hole with a diameter of Ø30 mm, a semi-cylindrical recess with a radius of R11, and stepped structural elements.

During the 3D modeling process, a basic prismatic shape is first created, after which the structural features are formed using cutting (cut) and adding (extrude) operations. By modeling holes and recesses in three-dimensional space, students gain a clear understanding of the actual spatial positions of hidden lines represented in two-dimensional drawings.

This example reveals the interrelationship between 2D drawings and the corresponding 3D model, thereby contributing to the development of students' spatial thinking as well as their skills in reading and analyzing engineering drawings.

The primary objectives of developing students' spatial thinking through three-dimensional modeling and forming skills in interpreting 2D drawings and converting them into 3D models include:

- analyzing the part's two-dimensional drawings;
- identifying the relationship between 2D and 3D representations;
- creating a three-dimensional model of the part using CAD software;
- conducting a design and engineering analysis based on the modeled part.

Task description: Based on the three principal projections provided (front, top, and side views), students are required to create a three-dimensional model of the part using CAD software such as AutoCAD, SolidWorks, or Kompas-3D. During the modeling process, the following steps should be followed:

1. Creating the basic prismatic shape of the part.
2. Forming the stepped section using the extrusion (extrude) method.
3. Creating the cylindrical hole with a diameter of Ø30 mm using the cutting (cut) operation.
4. Modeling the semi-cylindrical recess with a radius of R11.
5. Rotating the part around three axes in order to analyze the spatial arrangement and interrelationship of its structural elements.

Expected outcomes: As a result of completing the task, students are expected to:

• acquire spatial modeling skills;
• develop the ability to create three-dimensional models of complex parts based on 2D drawings;
• learn to think independently while reading and analyzing engineering drawings;
• improve their proficiency in working with modern CAD technologies.

Pedagogical significance: This didactic task integrates theoretical knowledge with practical activities in engineering graphics classes and contributes to the development of students' engineering thinking.

In conclusion, the present study was aimed at a comprehensive examination of the theoretical, methodological, and practical aspects of using spatial modeling and 3D technologies in engineering graphics education. The conducted analysis indicates that the integration of modern digital technologies into the engineering education process plays a significant role in updating educational content, enhancing teaching effectiveness, and forming students' professional competencies. The research findings reveal that classes conducted solely on the basis of traditional two-dimensional drawings have limited potential for developing students' spatial imagination.

In contrast, lessons organized using spatial modeling and 3D technologies provide opportunities for perceiving complex geometric forms in a visual and interactive environment, thereby effectively developing students' technical thinking, logical reasoning, and engineering imagination. Practical tasks performed using CAD systems in engineering graphics classes ensured a strong integration between theoretical knowledge and practical skills. In particular, the process of creating a 3D model based on 2D drawings, as demonstrated through the example of the given part, enabled students to gain a deeper understanding of the relationships between projections, visualize hidden elements in space, and analyze design solutions. As a result, the overall effectiveness of the learning process was significantly enhanced. Furthermore, the didactic tasks developed during the study demonstrated the feasibility of methodologically grounded integration of spatial modeling into the teaching process. These tasks contributed to the development of students' independent learning skills, their ability to analyze problem situations, and their competence in making engineering decisions.

Overall, the use of spatial modeling and 3D technologies in engineering graphics education represents an effective means of improving educational quality and holds substantial pedagogical significance in training competitive, highly qualified engineering professionals who meet the demands of the modern labor market. Continued research and methodological developments in this field will further contribute to the advancement of engineering education.

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