IMPROVING STUDENTS' SPATIAL PERCEPTION THROUGH CAD SOFTWARE IN GEOMETRY AND STEREOMETRY EDUCATION

Tsvetoslav Tsankov (1), Liliya Staneva (2)*

(1) Konstantin Preslavsky University of Shumen, Faculty of Technical Sciences, Shumen; (2) Burgas State University "Prof. Dr. Assen Zlatarov", Faculty of Technical Sciences, Burgas
Bulgaria

* Corresponding Author, e-mail: c.cankov@shu.bg

Abstract: The paper presents the application of CAD software to visualize and enhance understanding of spatial geometric concepts in stereometry education. Integrating CAD tools improves spatial thinking, supports teaching effectiveness, and helps overcome students' difficulties with mental transformations and interpreting 2D representations. As part of the STEM framework, CAD integration aids in visualizing and analyzing 3D objects while fostering analytical and engineering thinking. The study highlights the benefits of CAD systems for exploring spatial rotations, symmetries, and metric characteristics. This approach not only deepens students' comprehension of abstract geometry but also develops practical skills relevant to future careers in technology and engineering. The findings are based on an experimental study conducted with 48 university students using both traditional and CAD-based teaching methods.

Key words: artificial intelligence, CAD software, stereometry education, spatial thinking.

1. INTRODUCTION

Spatial thinking is a fundamental skill for understanding geometric concepts and applying them in various scientific and engineering fields. Stereometry education traditionally faces challenges related to students' difficulty in visualizing three-dimensional objects and transforming information from two-dimensional images into spatial constructs. Modern technologies, such as CAD systems, offer innovative solutions to these challenges. They enable visualization and manipulation of three-dimensional models, which significantly facilitates the understanding of complex geometric relationships. [1-4]

This article focuses on the application of CAD systems in stereometry education, examining their advantages and the possibilities for integration into the educational process. In addition, examples of educational tasks and approaches aimed at improving the effectiveness of teaching and material assimilation are presented. CAD software allows students to create, manipulate, and analyze both 2D and 3D objects. This supports the understanding of concepts such as:

- Visualization of three-dimensional figures and their transformation;
- Understanding of spatial rotations, reflections, and symmetries;
- Analysis of volume, surface, and other metric characteristics.

This transformation of static learning into a dynamic process fosters deeper comprehension and sustained student interest. It encourages learners to actively engage with geometric problems rather than passively observe them. As a result, students not only improve their spatial reasoning but also develop confidence in tackling complex visual tasks.

Among the popular CAD programs that can be used in education are AutoCAD, TinkerCAD, Fusion 360, Kompas, and GeoGebra 3D. They provide an intuitive interface and interactive tools for studying complex geometric structures. These features make CAD tools suitable not only for higher education but also for secondary school curricula with technical orientation. STEM education requires an interdisciplinary approach, combining mathematics, science, technology, and engineering. By using CAD in geometry and stereometry, the following is achieved:

- Better understanding of abstract concepts – students can visualize complex figures that would otherwise be difficult to represent on paper;
- Development of practical skills – CAD modeling is a core component in engineering sciences and architecture;
- Interactive learning – students can experiment with various parameters and analyze the results in real time;
- Creativity and innovation – CAD programs allow students to design and simulate their own constructions.

The use of CAD in geometry and stereometry education brings numerous benefits:

- Increased engagement and interest in the educational material;
- Improved spatial orientation and thinking;
- Preparation for future professions in engineering, architecture, and design;
- Skills for working with specialized software applicable in various scientific and technical fields.

2. MODERN TEACHING TOOLS

Stereometry education plays a key role in developing spatial thinking—an important skill for solving tasks related to the analysis and design of objects in three-dimensional space. Developing these skills is essential for students, especially in scientific and engineering fields. However, teaching this material often faces challenges such as students' difficulty in visualizing three-dimensional objects and the insufficient availability of interactive educational resources. [5, 7, 11, 14]

Modern technologies provide opportunities to overcome these challenges. The use of virtual reality, interactive applications, and 3D simulations allows students to grasp complex concepts in a more accessible and understandable way. Furthermore, CAD systems play a crucial role as a tool for visualization and education. They offer the ability to create and manipulate three-dimensional objects, which not only supports the understanding of spatial relationships but also stimulates creativity and analytical skills. The ability to actively construct and explore objects helps bridge the gap between theoretical knowledge and real-world applications.figure Figure 1 shows an image of a triangular prism with a cylindrical through-hole produced using CAD software.

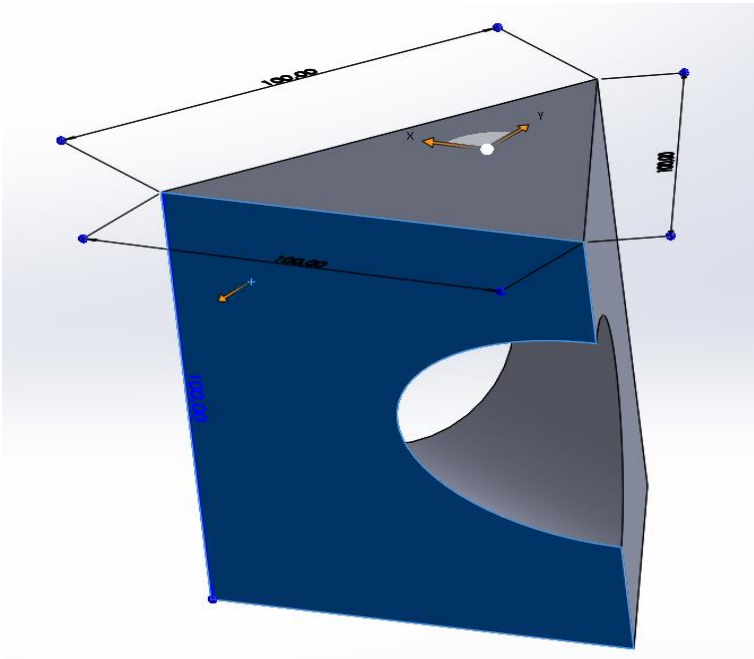

Figure 1. Triangular prism with a cylindrical through-hole.

These approaches contribute to modernizing the educational process by making it easier for teachers to present complex topics and by engaging students through practical applications of theoretical knowledge.

The similarity between developing 3D models in CAD systems and using artificial intelligence in education is reflected in the emphasis on visualization, creativity, and critical thinking. Both approaches require adapting the educational process to technological advancements and developing new skills for working with technologies that support the assimilation of complex concepts. [8-10, 19]

The three-dimensional figures generated by the chatbot are not entirely suitable for the intended purposes due to a lack of accuracy and detail. The chatbot's best result after a series of clarifications and corrections is shown in Figure 2. In this specific example, it is evident that the prism has no lateral faces – it consists only of bases – and the through-hole extends beyond them.

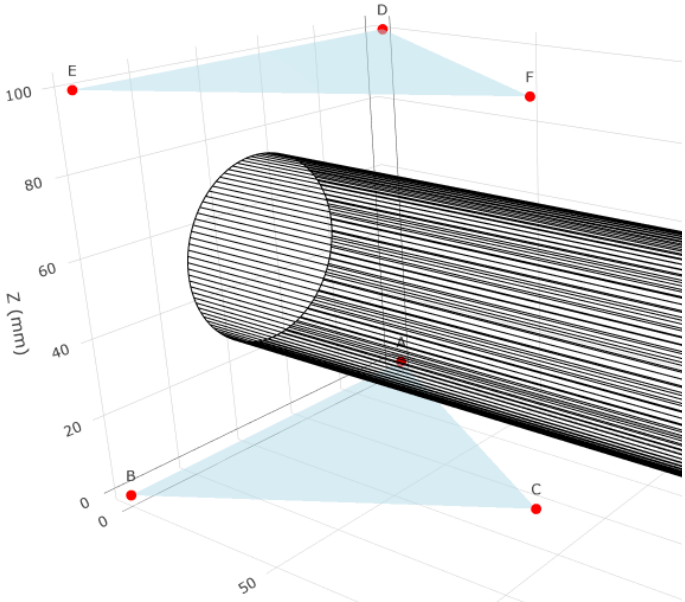

Figure 2. "Prism" with a hole, by artificial intelligence.

3. IMPROVING LEARNING THROUGH CAD

Integrating CAD systems into stereometry classes provides new opportunities for developing spatial thinking and the practical application of knowledge. Approaches for implementing these technologies include creating specialized lessons and tasks that focus on the visualization and analysis of three-dimensional objects. Educational materials are often designed to combine theory and practice through the design of real geometric constructions. While some AI-generated figures may lack precision, they still illustrate the potential of combining AI and CAD for educational purposes.

The teaching methods used include demonstrations with CAD software, individual and group projects, as well as interactive exercises in which students create and modify three-dimensional models. The evaluation of results is carried out through the analysis of completed assignments that demonstrate the level of mastery of spatial skills and the ability to apply theoretical knowledge in a practical setting. A particularly useful method is the use of assessment rubrics, which allow for objective and transparent feedback. [15-18]

Example lessons and tasks may include designing figures such as cubes, pyramids, and cones, as well as simulations of real constructions such as bridges or buildings. Application scenarios are often oriented towards problem solving—for example, calculating volumes and surfaces, optimizing constructions, or simulating interactions between objects. These tasks not only deepen the understanding of geometry but also encourage creativity and analytical thinking.

The use of CAD systems in stereometry education has a significant impact on the process of assimilating the material. Through the visualization and interactive capabilities of these software tools, students gain a better understanding of spatial relationships and the interconnections between geometric objects. Models created in CAD systems—such as detailed visualizations of pyramids, prisms, and complex 3D constructions—allow for easier and more intuitive comprehension of complex concepts. This intuitive grasp significantly reduces cognitive load and improves learning outcomes in tasks involving 3D perception. In order to save costs, software products that are free or very low-priced can be used solely for illustrative purposes (Figure 3).

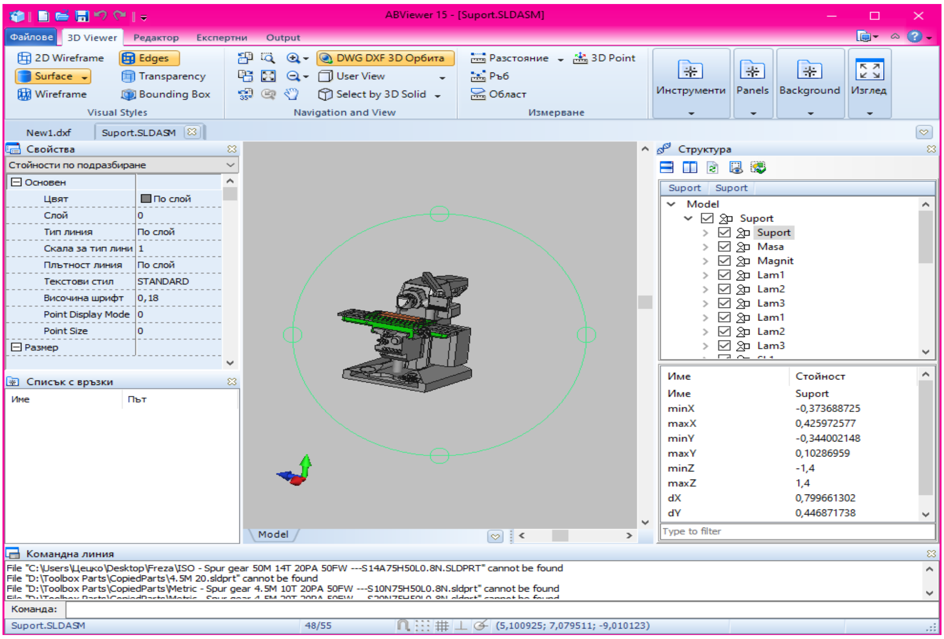

Figure 3. Software for viewing 3D objects.

To evaluate the effectiveness of CAD compared to traditional teaching methods, a comparative analysis was conducted based on the following criteria (Table 1).

Table 1. Comparative analysis based on experimental evaluation

Criteria	***Traditional methods***	***CAD integration***
Understanding of concepts	*3*	*5*
Interactivity	*2*	*5*
Visualization	*2*	*5*
Practical application	*3*	*5*
Student engagement	*2*	*5*
Preparation for professions	*3*	*5*

As can be seen from the analysis, the integration of CAD tools significantly improves all key aspects of education, especially in terms of interactivity, visualization, and practical application. The following graph illustrates the comparison between traditional methods and CAD integration based on the selected criteria (Figure 4).

The comparison between the traditional approach and the one using CAD software shows that implementing technology improves students' motivation and outcomes. While the traditional approach relies mainly on static images and manual drawings, CAD systems offer the possibility of dynamic object manipulation, which facilitates the understanding of volumes, cross-sections, and rotations.

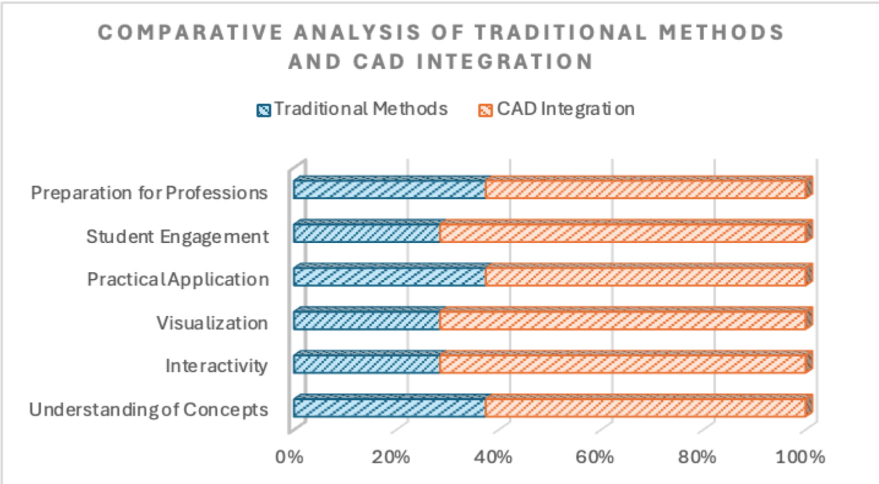

Figure 4. Comparative analysis of traditional methods and cad integration.

The advantages of CAD systems include better visualization, the ability to customize educational tasks, and the development of key skills such as creativity, analytical thinking, and technological literacy. However, the implementation of these systems may encounter challenges, such as the need for additional teacher training, provision of technical infrastructure, and integration of the software into existing curricula.

To overcome these challenges, it is recommended that teachers receive training in using CAD systems, that specialized educational materials be developed, and that best practices for classroom application be researched. Future studies may focus on the long-term effects of these technologies on spatial thinking and students' performance across various educational systems. [6, 12, 13]

To support the comparative analysis presented in Table 1, an experiment was conducted with a group of 48 students from two technical universities in Bulgaria. The students were divided into two groups of 24 each – one using traditional teaching methods and the other trained with the help of CAD systems (AutoCAD and GeoGebra 3D). All participants were second-year students studying technical sciences and had no prior experience with CAD. The training took place over a period of 5 weeks, with 2-hour sessions twice a week. The criteria in Table 1 were evaluated based on surveys, quizzes, practical assignments, and observation of engagement and performance during the sessions. The results reflect averaged evaluations made by both the instructors and the students themselves using a 5-point Likert scale.

4. CONCLUSION

The use of CAD systems in stereometry education significantly facilitates the understanding of complex figures and relationships in three-dimensional space. They enable the creation of realistic visualizations and models that help students see and practically grasp what would otherwise remain abstract. In this way, spatial thinking develops much faster and more effectively compared to traditional teaching methods. Incorporating CAD software into the educational process of geometry and stereometry significantly improves students' spatial perception. In the context of STEM education, this not only supports mathematical thinking but also creates a link between theory and practical application. By using digital tools, students acquire valuable skills that will be essential for their future academic and professional development.

Future analyses may focus on expanding the methodology for integrating CAD software into education, as well as on measuring its long-term effects on students' cognitive and analytical skills. In addition, research could explore the adaptation of CAD technologies to different age groups and educational disciplines for broader application in educational practice. Possible directions for future studies include empirical research on the impact of CAD on academic outcomes, comparative analyses between traditional and digital teaching methods, and the integration of CAD with other technological solutions, such as virtual and augmented reality. Ultimately, CAD integration not only transforms the way geometry is taught, but also aligns education with the demands of the digital era. The use of CAD in geometry and stereometry education offers numerous benefits:

- Increased engagement and interest in the educational material;
- Improved spatial orientation and thinking;
- Preparation for future professions in engineering, architecture, and design;
- Skills for working with specialized software that can be applied in various scientific and technical fields.

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Information about the authors:

Tsvetoslav Stanislavov Tsankov – Professor in Communication and Computer Technologies Department, Faculty of Technical Sciences, Konstantin Preslavsky University of Shumen. His research interests include communication networks, information security, pseudorandom sequence generation, and generalized net modeling. He is the author of numerous scientific papers, several textbooks, and holds patents and utility models in applied engineering and IT.

Liliya Anestieva Staneva – Associate Professor in the Department of Electronics, Electrical Engineering and Mechanical Engineering, Faculty of Technical Sciences, Burgas State University "Prof. Dr. Assen Zlatarov". She teaches courses such as Automation in Electronic Design and Analog Circuit Design. She has authored several peer-reviewed articles. Her research focuses on phase-manipulated signals, generalized net modeling, and signal processing using MATLAB. Her work has been cited in international studies related to signal synthesis and information security.

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