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PROBLEMS OF TEACHING ENGINEERING GRAPHICS IN HIGHER EDUCATION AND POSSIBILITIES OF A COMPUTER APPROACH

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Abstract: this article examines the current problems of teaching engineering graphics in higher education and evaluates the didactic possibilities of a computer-assisted approach in improving students' spatial thinking, graphic literacy, and creative competence. The study was conducted with students of Termez State University of Engineering and Agrotechnology within the subject "Descriptive Geometry and Engineering Graphics". A comparative pedagogical experiment was organized with an experimental group taught through computer-based tools, 3D visualizations, and interactive resources, while the control group was taught mainly through traditional methods. The results showed that the experimental group achieved a higher post-test score, stronger learning growth, and more positive dynamics in creative competence indicators. The findings suggest that systematic integration of digital tools into engineering graphics instruction can increase the effectiveness of learning and strengthen students' independent problem-solving skills.

Keywords: engineering graphics, higher education, computer-assisted instruction, spatial thinking, graphic literacy, digital tools, creative competence.

Introduction

Engineering graphics is one of the core disciplines in technical higher education. It forms students' ability to read, interpret, construct, and analyze technical drawings, as well as to understand the geometric structure of engineering objects. In road engineering, construction, mechanical design, architecture, and transport infrastructure, these competencies are directly connected with professional activity. For example, the design of highways, bridges, tunnels, road junctions, and structural details requires not only theoretical knowledge, but also spatial imagination, graphic accuracy, and the ability to solve positional and metric problems.

Despite its importance, engineering graphics remains one of the more difficult subjects for many first-year students. The difficulty is usually connected with the abstract nature of geometric concepts, insufficient development of spatial visualization, and the gap between theoretical explanation and practical drawing activity. In traditional teaching, students often learn by observing the teacher's demonstration and repeating ready-made examples. This method may help them understand a particular task, but it does not always develop independent problem-solving ability. As a result, when students face a new drawing problem, they may not know how to determine the correct sequence of actions.

The problem of solving complex educational tasks has long been discussed in pedagogical and methodological research. G.Pólya's step-by-step approach to problem solving emphasizes the importance of understanding the problem, preparing a plan, implementing the plan, and checking

the result [1]. This logic is also relevant to engineering graphics, where every drawing task requires a clear sequence of construction, analysis, and verification. From this point of view, engineering graphics should not be taught only as a set of drawing operations; it should be taught as a system of logical and spatial problem solving.

Another important theoretical foundation is cognitive load theory. J.Sweller showed that students' working memory has limited capacity and that poorly structured learning materials may increase unnecessary cognitive load [2]. In engineering graphics, this issue is especially important because students must simultaneously process visual, geometric, procedural, and technical information. If the teacher explains a complex drawing only verbally or through static examples, students may fail to understand the internal logic of the construction. Therefore, the learning process should be organized gradually, visually, and systematically.

R.Mayer's multimedia learning theory also supports the use of digital and visual materials in teaching complex subjects. According to this theory, students understand information more effectively when verbal explanations and visual representations are coordinated properly [3]. In engineering graphics, 3D models, dynamic animations, interactive drawings, and computer-based visualizations can help students imagine geometric objects more clearly. These tools are especially useful in explaining sections, projections, intersections, rotations, and transformations.

In recent years, international educational research has paid increasing attention to creative thinking, digital literacy, and problem-solving competence. The OECD report on creative thinking also emphasizes that modern education should prepare students to generate ideas, adapt solutions, and apply knowledge in new contexts [4]. This requirement is directly related to engineering graphics education, because students must not only copy drawings but also analyze technical situations, choose appropriate construction methods, and justify their decisions.

In Uzbek methodological literature, the teaching of descriptive geometry and engineering graphics has been studied as an important component of technical education. Y.Kirgizboev noted that the methodology of teaching descriptive geometry should be based on gradual explanation, visual clarity, and the development of spatial thinking [5]. E.Ro'ziyev and A.Ashirboyev also emphasized that engineering graphics instruction should form students' ability to read and prepare technical drawings correctly, while also developing their independent practical skills [6]. These views remain relevant today, but the rapid development of digital technologies requires updating existing methodological approaches.

Innovative educational technologies provide new opportunities for improving the teaching of engineering graphics. R.Ishmuxamedov's work on innovative educational technologies shows that the effectiveness of teaching increases when traditional explanation is combined with active, interactive, and technologically supported methods [7]. In addition, F. Alimova's research on constructive approaches to creativity development indicates that students' creative abilities grow more effectively when they are involved in practical, open-ended, and constructive tasks [8]. Therefore, the use of computer-assisted instruction in engineering graphics may serve not only to improve drawing skills but also to develop creative and spatial thinking.

At the same time, several contradictions can be observed in the current practice of teaching engineering graphics. First, modern engineering practice widely uses automated design systems, three-dimensional modelling, and digital visualization tools, but these tools are not always systematically integrated into the educational process. Second, graphical and analytical approaches are sometimes taught separately, which weakens students' ability to analyze engineering problems comprehensively. Third, many independent learning tasks remain reproductive in nature and do not

sufficiently stimulate creative activity. These contradictions show the need to study the effectiveness of a computer-assisted approach in engineering graphics education.

The purpose of this study is to analyze the main problems of teaching engineering graphics in higher education and to evaluate the didactic effectiveness of computer-based tools in developing students' graphic literacy, spatial thinking, and creative competence.

Materials and Methods

The study was conducted at Termez State University of Engineering and Agrotechnology with students studying road engineering-related disciplines. The research was organized within the subject "Descriptive Geometry and Engineering Graphics". The selected practical topic was related to showing the internal structure of a road structure detail by creating a cut or section in its drawing. This topic was chosen because it requires spatial imagination, technical drawing accuracy, understanding of projection principles, and the ability to interpret the internal structure of an engineering object.

The study used a comparative pedagogical experiment. The participants were divided into two groups. The experimental group consisted of 62 students and was taught using a computer-assisted approach. The control group consisted of 60 students and was taught using mainly traditional teaching methods. The initial level of both groups was determined through a pre-test. After the instructional intervention, a post-test was conducted to compare the learning outcomes.

The experimental group received instruction through digital tools, three-dimensional models, visual animations, and interactive resources. In this group, complex drawing operations were demonstrated step by step with the help of computer-based visualization. Students were able to observe how the section of a detail is formed, how hidden parts become visible, and how the internal structure is represented in a technical drawing. The use of digital tools also allowed students to review the material, compare their drawings with model examples, and correct mistakes independently.

The control group was taught using traditional methods. The teacher explained the topic through oral explanation, board drawings, printed examples, and standard practical assignments. Students completed drawing tasks mainly by following the teacher's demonstration. This method reflects the common practice of teaching engineering graphics, where the main focus is placed on explanation and reproduction of examples.

The assessment process included three main indicators. The first indicator was the average test score, measured through pre-test and post-test results. The second indicator was the growth rate, which showed how much the students' results improved after instruction. The third indicator was the level of creative competence, which was analyzed through students' ability to complete drawing tasks independently, propose alternative solutions, use visual reasoning, and explain the logic of their work.

The statistical analysis was carried out by comparing the pre-test and post-test results of the two groups. A t-test was used to determine whether the difference between the groups was statistically significant. The level of significance was set at $p < 0.001$. This made it possible to identify whether the observed improvement in the experimental group was connected with the computer-assisted approach rather than accidental variation.

Results

The initial diagnostic results showed that the two groups were almost equal before the instructional intervention. The average pre-test score of the experimental group was 54.2 points, while the control group scored 53.8 points. The difference between the groups at the initial stage

was only 0.4 points. This means that both groups started the experiment with a similar level of knowledge and practical skills in engineering graphics.

After the instructional intervention, the experimental group demonstrated a much higher result. The average post-test score of the experimental group reached 78.6 points, while the control group achieved 61.5 points. The difference between the post-test results was 17.1 points in favor of the experimental group. This result shows that the computer-assisted approach had a clear positive effect on students' mastery of the topic.

Indicator	Experimental group	Control group	Difference
Average score (pretest)	54.2	53.8	0.4
Average score (posttest)	78.6	61.5	17.1
Growth rate	45.0%	14.3%	30.7%

The growth rate also confirms the effectiveness of the computer-assisted approach. In the experimental group, the learning growth was 45.0%, while in the control group it was 14.3%. The difference between the growth rates was 30.7%. This indicates that students who learned through digital tools, 3D visualizations, and interactive resources mastered the topic more effectively than students who were taught through traditional methods.

The statistical analysis showed that the difference between the post-test results of the two groups was significant at $p < 0.001$. This means that the improvement observed in the experimental group was not random. The computer-assisted approach created better conditions for understanding the topic, especially for tasks related to internal structure, section formation, and spatial interpretation of engineering objects.

The indicators of creative competence also showed positive dynamics. In the experimental group, the share of students with a high level of creative competence increased from 11% to 38%. At the same time, the share of students with a low level decreased from 49% to 16%. These changes show that the computer-assisted approach influenced not only test results, but also students' ability to think independently, analyze the structure of a technical object, and complete drawing tasks with greater confidence.

In the control group, positive changes were also observed, but they were less pronounced. This suggests that traditional teaching methods can provide a certain level of knowledge and practical skill formation. However, their effect is limited when compared with computer-based methods, especially in the development of spatial imagination and independent drawing activity.

The practical work results showed that students in the experimental group made fewer mistakes in identifying the section plane, representing the internal structure of the detail, and maintaining the logical connection between different views of the drawing. They also showed better understanding of how a three-dimensional object is transformed into a two-dimensional technical representation. These results are important because they reflect the practical value of digital visualization in engineering graphics education.

Discussion

The results of the study confirm that a computer-assisted approach can significantly improve the quality of teaching engineering graphics in higher education. The main advantage of this

approach is that it makes invisible or difficult-to-imagine geometric processes more understandable. In traditional teaching, students often see only the final drawing or the teacher's step-by-step board explanation. In computer-assisted teaching, however, students can observe the object dynamically, rotate it mentally and visually, analyze its internal structure, and understand the relationship between views more clearly.

The findings are consistent with Pólya's problem-solving approach, because digital tools help students follow the sequence of analysis, planning, construction, and verification [1]. When students work with a section drawing, they first understand the object, then identify the section plane, then construct the view, and finally check the correctness of the result. Computer-based visualization supports each of these steps and makes the whole process more transparent.

The results also support cognitive load theory. Engineering graphics tasks can overload students' working memory if they must simultaneously imagine the object, understand the projection rule, follow construction steps, and avoid technical drawing errors [2]. Digital visualization reduces unnecessary cognitive load by presenting complex spatial information in a clearer and more structured form. This allows students to focus more on the logic of the task rather than on guessing the shape of the object.

Mayer's multimedia learning theory also helps explain why the experimental group achieved better results [3]. The combination of verbal explanation, visual demonstration, and interactive modelling creates more favorable learning conditions than verbal explanation alone. In particular, 3D animations and digital models help students connect abstract geometric rules with concrete visual images. This is especially important for first-year students who are still developing spatial thinking.

The positive dynamics of creative competence in the experimental group can be explained by the fact that digital tools create more opportunities for experimentation. Students can test different views, compare alternatives, correct mistakes, and see the result of their actions quickly. This supports the development of creative thinking, which is increasingly recognized as an important educational outcome in modern higher education [4]. In engineering graphics, creativity does not mean arbitrary drawing. It means the ability to choose a rational solution, interpret a technical object correctly, and present it clearly through graphic means.

The results also correspond to national methodological views on teaching descriptive geometry and engineering graphics. The need for gradual explanation, visual clarity, and practical orientation has been emphasized in Uzbek methodological literature [5], [6]. However, the present study shows that these principles become more effective when supported by computer-based tools. Digital visualization does not replace traditional drawing culture; rather, it strengthens it by helping students understand the spatial basis of technical representation.

The study also confirms the relevance of innovative educational technologies in engineering graphics instruction. As noted in pedagogical research, innovative methods increase the effectiveness of teaching when they are connected with the content and purpose of the subject [7]. In this study, digital tools were not used as additional decoration. They were directly connected with the main learning task: understanding the internal structure of a road engineering detail and representing it correctly through a section drawing.

The development of creative competence is also closely connected with constructive learning. F. Alimova's view that creativity develops more effectively through constructive and practical tasks is relevant here [8]. In the experimental group, students were not limited to repeating the teacher's example. They had the opportunity to analyze the object, check different variants, and correct their solutions. This increased their independence and supported creative problem solving.

Recent studies on composition and creative abilities also show that visual thinking develops when students consciously analyze form, structure, and proportion [9]. Although engineering graphics is a technical subject, it also requires visual culture and compositional accuracy. A technical drawing must be not only correct, but also clear, readable, and logically organized. Therefore, the development of graphic literacy is closely related to the development of disciplined visual thinking.

The relevance of digital tools is further supported by research on AutoCAD and three-dimensional design possibilities [10]. Computer-aided design systems allow students to understand spatial relationships more deeply and prepare them for professional engineering practice. At the same time, studies on AutoCAD-based competence formation show that digital tools are effective only when they are integrated into a clear methodological framework [11]. This is why the computer-assisted approach should be systematic, not episodic.

The use of innovative methods in engineering and computer graphics instruction has also been identified as an important factor in improving students' professional readiness [12]. In the present study, the experimental group's higher results show that digital tools can strengthen students' knowledge, practical drawing skills, and problem-solving ability. Similar conclusions can be drawn from studies on smart museum technologies, where interactive digital environments help users understand technical and industrial processes more clearly [13]. This shows that visualization technologies have wide didactic potential in technical education.

The importance of teaching engineering and computer graphics in higher education is also related to the formation of technical imagination and professional communication [14]. Engineers communicate many ideas through drawings, schemes, models, and visual representations. Therefore, improving the methodology of engineering graphics instruction has direct professional importance.

At the same time, technical education should not be separated from cultural, aesthetic, and pedagogical dimensions. Research on beauty and moral education in Eastern pedagogy shows that the educational process can be enriched by combining professional knowledge with broader cultural values [15]. Similarly, pedagogical studies on the educational use of Eastern thinkers' aesthetic views emphasize the importance of developing students' worldview, responsibility, and aesthetic sensitivity [16]. In engineering graphics, this means that technical accuracy should be combined with visual clarity, responsibility, and respect for professional standards.

Nevertheless, the study has certain limitations. First, the experiment was conducted in one higher education institution, so the results should be tested in other universities and technical programs. Second, the study focused on one practical topic related to section drawing. Future research may include other topics such as projections, intersections, axonometric drawings, and computer-aided modelling. Third, the study measured immediate learning outcomes; long-term retention and transfer of skills should also be examined in future research.

Despite these limitations, the findings provide practical evidence that a computer-assisted approach can improve engineering graphics education. The approach is especially useful when it is applied systematically, connected with the subject content, and supported by appropriate assessment criteria. It helps students not only understand the material better but also develop spatial thinking, independent work skills, and creative competence.

Conclusion

The study showed that the computer-assisted approach is more effective than traditional teaching methods in teaching engineering graphics. The experimental group achieved a post-test score of 78.6 points, while the control group achieved 61.5 points. The growth rate in the

experimental group was 45.0%, compared with 14.3% in the control group. The difference between the groups was statistically significant at $p < 0.001$.

The results indicate that computer-based tools, 3D visualizations, and interactive resources create favorable conditions for developing students' spatial thinking, graphic literacy, and creative competence. Digital tools help students understand complex geometric processes, reduce cognitive difficulty, and improve independent problem-solving. At the same time, the findings show that traditional methods should not be completely rejected. The most effective approach is to combine traditional drawing culture with modern digital technologies.

Based on the results of the study, the following recommendations can be proposed. First, digital tools should be integrated into engineering graphics instruction systematically rather than occasionally. Second, teachers should increase the share of problem-based and project-based drawing tasks. Third, assessment criteria should include not only the final drawing result, but also the solution process, independence, originality, and accuracy. Fourth, teachers' digital competence should be improved through practical training courses. Fifth, independent learning should be organized through digital platforms that support self-study, reflection, and correction of mistakes.

In general, the computer-assisted approach represents an important methodological direction for improving the quality of engineering graphics education in higher education. It supports the transition from reproductive learning to active, visual, problem-based, and professionally oriented learning.

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