

Maulana Advances in Inclusive Education

Vol. 2 No. 1 2026

ISSN: 3105-0107

Website : https://maulanapress.com/index.php/maulana

Organizing Design Activities in the Kompas-3D Environment in Engineering Education: Didactic Models and Professional Competencies

PhD Umarov Abdutasul Abdurahimovich*[1]

Doctoral candidate, National Pedagogical University of Uzbekistan named after Nizamiy

Article information

DOI : xxx

*Correspondence :

Submission Track

Submission : July 30, 2026
Final Review : August 15, 2026
Accepted : August 30, 2026
Available online : September 23, 2026

Keywords

engineering education, KOMPAS-3D, computer-aided design system, CAD/CAE, parametric modelling, spatial ability, project-based learning, professional competencies.

Abstract

This article examines the didactic potential of using the KOMPAS-3D computer-aided design system in engineering education and approaches to integrating it into learning activities aimed at developing professional competencies. Within a theoretical and analytical study, research published between 2020 and 2026 on CAD/CAE education, spatial ability, project-based learning, and the educational use of KOMPAS-3D was comparatively reviewed. The analysis substantiates the need to organize digital design not merely as the acquisition of individual software commands, but as a sequence of learning stages: defining an engineering problem, building a parametric model, preparing technical documentation, checking an assembly structure, and justifying a design solution. A didactic sequence is proposed that links KOMPAS-3D assignments with digital design, engineering graphics, constructive and analytical, and practical design competencies. The article does not claim to measure experimental effectiveness; its conclusions are based on the analysis of selected scholarly sources and the author's didactic synthesis.

This is an open access article under the CC BY-NC license
https://creativecommons.org/licenses/by-nc/4.0/

INTRODUCTION

The digital transformation of engineering practice is changing the requirements placed on the design process. Engineers are expected not only to create the geometric shape of a technical object, but also to manage its parametric structure, take account of design constraints, prepare technical documentation, and evaluate the implications of design decisions. For this reason, computer-aided design systems (CAD) in engineering education should be treated not simply as software skills to be acquired, but as an integral part of the ability to solve engineering problems.

The interaction between computer-aided design (CAD) and computer-aided engineering (CAE) tools

plays an important role in the product development cycle. Khan and Rezwana [1] examine issues related to the integration of CAD models with CAE analysis and emphasize the continuity between geometric modelling and engineering analysis. The integration of CAD, CAE, and CAM into engineering curricula through project-based learning has also been reported as a way to connect software use with practical design tasks and collaborative problem-solving [2]. From an educational perspective, this approach enables students to understand a model not merely as an image, but as engineering information that can serve as a basis for subsequent analysis and the preparation of manufacturing documentation.

KOMPAS-3D is an environment used for parametric three-dimensional modelling, the creation of parts and assemblies, and the preparation of engineering documentation. However, the educational value of using the software is determined not by the number of its functions, but by the content and complexity of learning tasks, the feedback provided, and the assessment criteria. A study published in 2026 comparing KOMPAS-3D and nanoCAD from the perspective of students' geometric and graphic training also indicates that the selection of a CAD platform should take into account didactic features of the learning process alongside technical functionality [3].

The aim of this article is to substantiate a didactic sequence for organizing design activities in the KOMPAS-3D environment and to identify the relationship between these activities and the professional competencies they may help develop.

METHODOLOGY

This article is theoretical and analytical in nature. The research material consists of scholarly articles published between 2020 and 2026 that are directly related to CAD/CAE integration, 3D CAD education, spatial ability, project-based learning, and the educational use of KOMPAS-3D. The selection of sources took into account their relevance to the topic, the availability of bibliographic identifiers (DOI or an official journal webpage), the presence of volume, issue, and page information, and the transparency of the research methods. The selection should not be interpreted as a comprehensive systematic literature review (SLR) or as a full search conducted in accordance with the PRISMA protocol.

Bibliographic and comparative analysis, thematic grouping, and pedagogical synthesis were used. The scholarly sources were considered in four areas: (1) integration of CAD/CAE tools into engineering education; (2) 3D modelling and spatial ability; (3) project-based learning and pedagogical scaffolding; and (4) the role of KOMPAS-3D in geometric and graphic training. These areas provided the basis for developing a didactic sequence for learning tasks.

The proposed sequence is not the result of an empirical experiment. Rather, it is an author-developed didactic model formed by bringing together the reviewed sources and the logical stages of engineering design activity.

Research on teaching CAD/CAE tools highlights the need to connect digital design with practical engineering tasks. Berselli, Bilancia, and Luzi [4] discuss the teaching of advanced CAD/CAE tools through project-based learning and demonstrate the potential for integrating parametric design and engineering analysis within a single learning activity. This approach places greater emphasis on students' step-by-step resolution of design problems than on memorizing software commands.

A broader review of CAD software in engineering graphics education identifies visualization, analysis, and collaboration as important contributions of digital design tools, while also noting differences in institutional access and curriculum integration [5]. Reviews of project-based learning in engineering education further emphasize that authentic projects can support the development of technical and transferable competencies, provided that project work is aligned with curriculum objectives and supported by appropriate assessment [6], [7].

Spatial ability is an important pedagogical dimension of 3D CAD education. Dilling and Vogler [8] examine the potential of CAD software for fostering spatial ability through a case study. Their work highlights the educational value of activities such as viewing an object from different directions, rotating it in a three-dimensional environment, and perceiving geometric relationships. However, improvement in spatial ability should not be treated as a guaranteed outcome of software use alone; learning tasks need to be purposefully and systematically designed. The broader educational significance of spatial ability for STEM learning has also been emphasized in recent research [9]. Studies using augmented reality in learning environments have additionally examined the relationship between three-dimensional visualization, spatial ability, and learning performance [10].

Sola-Guirado and colleagues [11] investigate the teaching of CAD/CAM/CAE tools through project-based learning in a virtual distance-learning environment. Their study emphasizes the importance of connecting project tasks, digital resources, and teacher support within a coherent learning process. Uslu, Durak, and Ay [12] compare reflective and supportive scaffolding in a 3D CAD course involving 118 mechanical engineering students. The authors report higher levels of metacognitive strategies and spatial ability self-efficacy in the group receiving supportive scaffolding.

Evidence from a large repeated cross-sectional analysis of a university CAD course suggests that structured practice and feedback are particularly important when students move from basic software procedures to more complex modelling tasks [13]. This finding supports the use of staged assignments and formative feedback rather than relying exclusively on passive instructional materials.

In their study of project-based learning outcomes in a CAD course, Wang, Jansrisukot, and Narjikaew [14] combined project assignments and WebQuest resources over one semester with 38 undergraduate engineering students. The authors report an increase in innovation ability scores across repeated measurements. However, because the study did not include a control group, causal interpretations of the findings should be made cautiously.

Nazarova's [3] study, published in 2026, directly addresses the educational use of KOMPAS-3D by comparing KOMPAS-3D and nanoCAD from the perspective of geometric and graphic training. The study supports the need to consider factors such as the interface, the sequence of parametric modelling operations, the preparation of technical documentation, and the availability of learning resources when selecting software.

Recent empirical work on AutoCAD-based spatial learning has examined the association between CAD-supported learning and students' perceived visualization skills in engineering education [15]. In a related direction, a 2026 study in engineering graphics education reports an instructional model that combines drawing, modelling, and verification through augmented reality, highlighting the value of connecting

graphical representations with three-dimensional objects [16].

Taken together, the reviewed sources point to several general implications. CAD education should be based on authentic or realistic engineering tasks. Three-dimensional modelling can create opportunities to develop spatial visualization and parametric thinking, but these opportunities require methodological support. Learning outcomes should therefore be assessed not only in terms of software skills, but also in terms of students' ability to analyse, justify, and document engineering solutions.

RESULTS AND DISCUSSION

A didactic sequence for design activities in the KOMPAS-3D environment. The analysis suggests that work with KOMPAS-3D can be organized into five interrelated stages: understanding the engineering task; creating a parametric part model; preparing a technical drawing based on the model; integrating individual parts into an assembly; and checking and presenting the design solution. This sequence moves students beyond isolated software operations towards a coherent engineering design cycle.

At the first stage, students interpret the technical specification, identify the function and operating conditions of the object, and determine the required dimensions and constraints. At this stage, the instructor should go beyond demonstrating a completed model and encourage students to explain why a particular design solution has been selected.

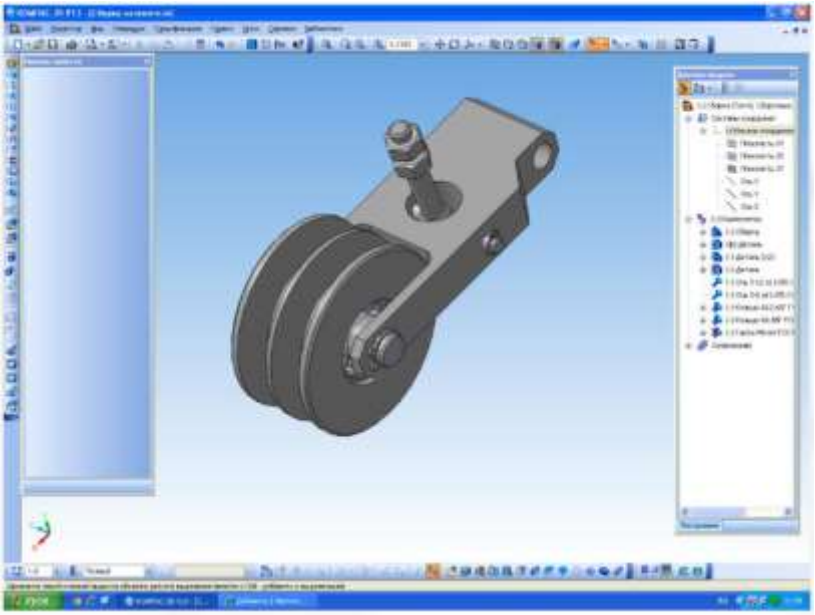

Figure 1. A 3D model of a roller-support component within a pulley mechanism in the KOMPAS-3D environment (image provided by the author).

At the second stage, students create a 3D model of the part. They learn to understand the relationships between sketches, geometric constraints, dimensions, and parametric operations. Observing how changes in parameters affect the model encourages students to manage the structure of a design consciously rather than merely drawing its shape.

At the third stage, students prepare a working drawing based on the 3D model. They check the adequacy of views, sections, dimensions, and technical requirements. An automatically generated drawing

should not be accepted as a finished manufacturing document without review; it must be checked by the engineer. This requirement develops technical responsibility alongside graphic literacy.

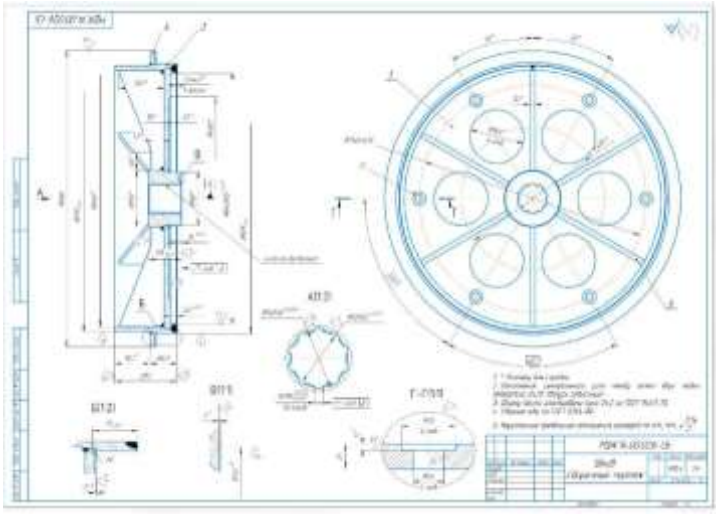

Figure 2. Working drawing of a pulley component prepared in the KOMPAS-3D environment (image provided by the author).

At the fourth stage, individual parts are combined into an assembly model. Students define the positioning and connection relationships between parts and check for possible mismatches or interference. The analysis should focus not only on the external appearance of the assembly, but also on the functional and geometric relationships between its components.

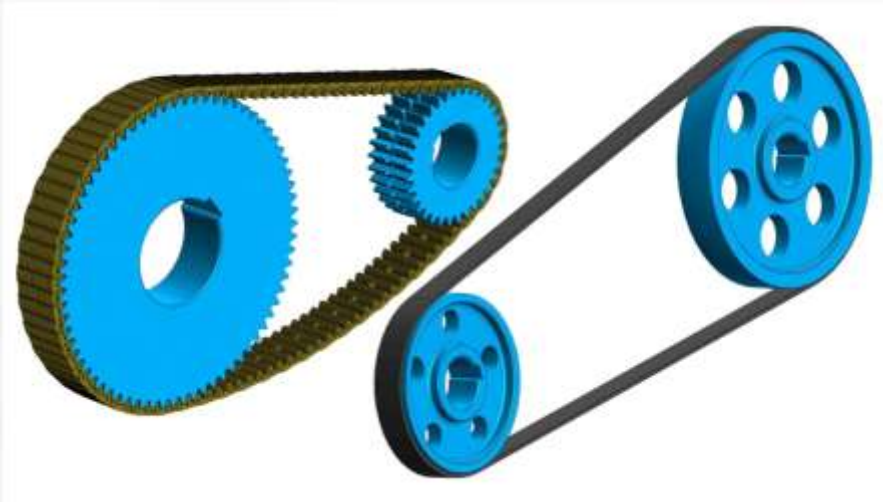

Figure 3. Assembly representation of belt-drive components in the KOMPAS-3D environment (image provided by the author).

At the fifth stage, students present the completed project. They explain the consistency between the technical specification, 3D model, working drawing, and assembly model, and justify the advantages and limitations of the selected solution. This stage complements design activity with communication and reflection.

Didactic stages and the competencies they support

Table 1. Learning Stages, Student Activities, and Competencies Developed in the 3D Design Process

Learning stage	Main student activity	Competency developed
1. Task analysis	Interpreting the technical specification and identifying requirements and constraints	Engineering and analytical
2. 3D modelling	Defining sketches, parameters, geometric constraints, and design features	Digital design; spatial
3. Drawing preparation	Preparing views, sections, dimensions, and technical requirements	Engineering graphics
4. Assembly modelling	Positioning parts and checking connections and compatibility	Constructive and systems-oriented
5. Project presentation	Justifying decisions, explaining errors, and presenting documentation	Practical design; communication; reflection

The table shows that learning activities in KOMPAS-3D do not end with the creation of a digital model. Their pedagogical value increases when they encompass the entire process, from analysing the technical specification to presenting and defending the final design decision. This approach is consistent with the project-based teaching of CAD/CAE discussed by Berselli and colleagues [4], as well as the sequence of project tasks used in the study by Wang and colleagues [14].

Mechanisms for developing professional competencies

Digital design competency — developed through creating parametric models, managing dimensions and geometric constraints, editing models, and preparing files in appropriate formats.

Engineering graphics competency — developed through representing spatial objects in projections, selecting sections and cross-sections, adding dimensions, and checking drawing quality against applicable standards.

Constructive and analytical competency — developed through analysing the function of a part, its loading conditions, design constraints, and compatibility with other components in an assembly.

Practical design competency — developed through planning and completing work from the interpretation of a technical specification to the preparation of the final model and documentation, and justifying the result.

Reflective and communication competencies — developed through identifying errors, responding to feedback, comparing alternative solutions, and presenting and defending design decisions.

Research on the development of spatial ability [8, 12] indicates the importance of providing students with step-by-step support, dividing complex tasks into manageable operations, and encouraging them to explain their own work. Accordingly, rather than simply demonstrating a finished solution, instructors should use guiding questions, intermediate checks, and criteria-based feedback. Such scaffolding is consistent with research showing the value of structured, blended learning activities for spatial visualization and engineering graphics practice [10], [16].

Recommendations for assessment. When assessing KOMPAS-3D assignments, it is not sufficient to consider only the external appearance of the final model. Assessment criteria should cover compliance with the technical specification; the logical structure of the parametric model; geometric accuracy; consistency between the drawing and assembly model; justification of the design decision; the ability to identify and correct errors independently; and the clarity of project documentation. These criteria enable instructors to distinguish students' ability to perform software operations from their engineering thinking.

Observable indicators and performance levels should be defined in advance for each criterion in the assessment rubric. If an educational institution intends to investigate changes in competency development empirically, it should separately design baseline and final tasks, expert assessment procedures, a control group, and methods for checking reliability. No such experiment is reported in this article.

CONCLUSION

The analysis indicates that the educational value of KOMPAS-3D in engineering education depends on how effectively its technical capabilities are incorporated into a coherent learning process. When students use the software to interpret an engineering task, develop a parametric model, prepare and verify technical documentation, assemble components, and explain the reasoning behind their design decisions, digital modelling becomes more than an exercise in operating a software package: it becomes a means of engaging with the logic of engineering practice.

For this reason, KOMPAS-3D-based instruction should be organized around meaningful design problems that gradually increase in complexity and require students to connect geometric modelling with engineering graphics, constructive analysis, and practical decision-making. Instructors are encouraged to combine demonstrations with guided independent work, structured feedback, peer discussion, and assessment criteria that value not only the accuracy of the final model but also the reasoning and process through which it was produced. The proposed didactic sequence may serve as a methodological basis for designing such learning activities. Its practical effectiveness should be examined in future classroom-based research using clearly defined competency indicators and appropriate experimental procedures.

REFERENCES

[1] M. T. H. Khan and S. Rezwana, "A review of CAD to CAE integration with a hierarchical data format (HDF)-based solution," *Journal of King Saud University–Engineering Sciences*, vol. 33, no. 4, pp. 248–258, May 2021, doi: 10.1016/j.jksues.2020.04.009.

[2] F. A. O. Fernandes, N. Fuchter Júnior, A. Daleffe, D. Fritzen, and R. J. Alves de Sousa, "Integrating CAD/CAE/CAM in engineering curricula: A project-based learning approach," *Education Sciences*, vol. 10, no. 5, Art. no. 125, 2020, doi: 10.3390/educsci10050125.

[3] Z. A. Nazarova, "Choosing a basic computer-aided design system for students' geometric and graphic training: A comparative analysis of KOMPAS-3D and nanoCAD," *Modern High Technologies*, no. 9, pp. 229–234, 2026, doi: 10.17513/snt.40945.

[4] G. Berselli, P. Bilancia, and L. Luzi, "Project-based learning of advanced CAD/CAE tools in engineering

education," *International Journal on Interactive Design and Manufacturing*, vol. 14, pp. 1071–1083, 2020, doi: 10.1007/s12008-020-00687-4.

[5] M. Koziar, H. Hubal, I. Burchak, M. Botviniev, and D. Saveliev, "The impact of CAD software on the teaching of engineering graphics: A systematic review," *Periodicals of Engineering and Natural Sciences*, vol. 13, no. 1, pp. 17–39, 2025, doi: 10.21533/pen.v13.i1.278.

[6] S. Lavado-Anguera, P.-J. Velasco-Quintana, and M.-J. Terrón-López, "Project-based learning (PBL) as an experiential pedagogical methodology in engineering education: A review of the literature," *Education Sciences*, vol. 14, no. 6, Art. no. 617, 2024, doi: 10.3390/educsci14060617.

[7] M. Ramírez de Dampierre, M. C. Gaya-López, and P. J. Lara-Bercial, "Evaluation of the implementation of project-based-learning in engineering programs: A review of the literature," *Education Sciences*, vol. 14, no. 10, Art. no. 1107, 2024, doi: 10.3390/educsci14101107.

[8] F. Dilling and A. Vogler, "Fostering spatial ability through computer-aided design: A case study," *Digital Experiences in Mathematics Education*, vol. 7, pp. 323–336, 2021, doi: 10.1007/s40751-021-00084-w.

[9] T. Ishikawa and N. S. Newcombe, "Why spatial is special in education, learning, and everyday activities," *Cognitive Research: Principles and Implications*, vol. 6, Art. no. 20, 2021, doi: 10.1186/s41235-021-00274-5.

[10] D. Elford, S. J. Lancaster, and G. A. Jones, "Exploring the effect of augmented reality on cognitive load, attitude, spatial ability, and stereochemical perception," *Journal of Science Education and Technology*, vol. 31, pp. 322–339, 2022, doi: 10.1007/s10956-022-09957-0.

[11] R. R. Sola-Guirado, G. Guerrero-Vacas, and Ó. Rodríguez-Alabanda, "Teaching CAD/CAM/CAE tools with project-based learning in virtual distance education," *Education and Information Technologies*, vol. 27, pp. 5051–5073, 2022, doi: 10.1007/s10639-021-10826-3.

[12] N. Atman Uslu, H. Yildiz Durak, and G. M. Ay, "Comparing reflective and supportive scaffolding in 3D computer-aided design course: Engineering students' metacognitive strategies, spatial ability self-efficacy, and spatial anxiety," *Computer Applications in Engineering Education*, vol. 30, no. 5, pp. 1454–1469, 2022, doi: 10.1002/cae.22531.

[13] I. Vasileska, N. Vukašinović, and V. Čok, "Balancing homework and video instruction: A repeated cross-sectional analysis of CAD course outcomes," *Education Sciences*, vol. 16, no. 5, Art. no. 731, 2026, doi: 10.3390/educsci16050731.

[14] J. Wang, J. Jansrisukot, and P. Narjikaew, "Effect of integrating project-based learning and WebQuests to enhance innovation ability of Chinese undergraduate engineering students: CAD course," *Higher Education Studies*, vol. 15, no. 4, pp. 536–550, 2025, doi: 10.5539/hes.v15n4p536.

[15] T. H. T. Nguyen, V. L. Truong, and T. S. Tran, "No student left behind in engineering education: An empirical study on AutoCAD-based spatial learning and its associations with visualization skills in developing countries," *Computer Applications in Engineering Education*, vol. 34, no. 2, Art. no. e70157, 2026, doi: 10.1002/cae.70157.

[16] Y. Wang, H. Wang, X. Cheng, T. Sun, et al., "Innovation and practice of an augmented reality-based teaching model for engineering graphics education," *International Journal of Mechanical Engineering Education*, published online Sep. 17, 2026, doi: 10.1177/03064190261486587.