International Journal of Innovative Research and Scientific Studies, 8(4) 2025, pages: 460-467

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Teaching 3D engineering modeling and prototyping in Creo parametric in educational institutions

Saniya Nariman[1], Maxot Rakhmetov[2], Gulmira Nurbekova[3], Gulnur Issakova[4*], Balaussa Orazbayeva[5]

[1,3,4,5]L.N. Gumilyov Eurasian National University, Astana, Kazakhstan.
[2]Kh.Dosmukhamedov Atyrau University, Atyrau, Kazakhstan.

Corresponding author: Gulnur Issakova (*Email: gulnurisakova001@gmail.com*)

Abstract

This article presents a comparative analysis of the capabilities of the Creo Parametric graphics system in comparison with other popular software products. Special attention is paid to the specifics of working with assemblies in the full-featured NX CAD system, as well as the process of creating a three-dimensional model of a part in SolidWorks. The application areas of graphics systems such as NX and CATIA are also considered. The principle of building a 3D model in the T-FLEX CAD system is investigated. In addition, the possibilities, approaches, and principles of operation of applications of the Creo Parametric graphics system are analyzed. To improve the performance and quality of work in graphics systems, it is recommended to use each of them in those areas of industry where they demonstrate clear advantages. In the engineering industry, the use of the Creo Parametric CAD system is especially advantageous, as it allows you to combine two approaches — parametric and direct modeling. Furthermore, it is convenient to work with small applications and supports the import of formats from computer-aided design (CAD) systems from other manufacturers.

Keywords: 3D modeling, Assembly, CAD systems, CATIA, Creo Parametric, Direct modeling, Engineering graphics, NX CAD, Parametric modeling, SolidWorks, T-FLEX CAD.

DOI: 10.53894/ijirss.v8i4.7872
Funding: This study received no specific financial support.
History: Received: 25 April 2025 / **Revised:** 29 May 2025 / **Accepted:** 31 May 2025 / **Published:** 18 June 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: SN, MR wrote the paper and designed it; collected and analyzed the results of the work; GN, GO, BO carried out the work on conceptualizing the paper and critically analyzing its content; Both authors read and approved the final version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

In the modern era, computer technologies have become an integral component of various aspects of human activity. Many industrial sectors now rely on computational tools to accelerate and enhance the problem-solving process. Historically, computers functioned primarily as auxiliary instruments, assisting with calculations while humans performed the core analytical and creative work. However, the growing complexity of contemporary challenges, ranging from large-scale engineering projects to advanced technology development and simulation, necessitated more sophisticated tools [1].

The advent of high-performance graphics workstations and computational systems capable of visualizing intricate technological processes has ushered in a new era in the field of computer-aided design and engineering [2]. These developments have transformed computers from passive calculators into active participants in design, analysis, and innovation.

The primary objective of integrating 3D engineering modeling into education is to cultivate a creative and proactive student who is proficient in modern information and communication technologies. Such a learner should be capable of independent inquiry, original discovery, informed decision-making, and accountability for outcomes [3].

The specific goals of this pedagogical innovation include:

- Developing students' practical skills in the field of engineering graphics and computer modeling.
- Maximizing the use of technological resources to enhance the quality of 3D modeling instruction.
- Continuously enriching students' digital literacy through creative and individualized activities within the course "Computer Graphics and Engineering Graphics".
- Strengthening students' spatial thinking and visualization skills.
- Promoting self-confidence and the understanding that a successful career path is built on creativity and critical engagement.

Three-dimensional graphics now play a crucial role in both scientific research and industrial practice. They are widely employed in computer-aided design (CAD) systems for the modeling of mechanical components, architectural structures, and complex mechanisms. Beyond engineering, 3D graphics are integral to architectural visualization, virtual archaeology, medical imaging, and have gained prominence in entertainment industries such as gaming, cinema, and digital publishing [4].

Despite the variety of methods available for representing three-dimensional information, many rely on perceptual approximations such as stereoscopic images viewed through 3D glasses, virtual reality headsets, or specialized displays [5]. These technologies simulate volume perception on flat surfaces, offering immersive visualization experiences [6].

In the context of engineering education, the implementation of 3D modeling using advanced CAD platforms has shown significant pedagogical value. One of the most powerful tools in this domain is PTC Creo Parametric, a feature-rich, flexible system designed to accelerate the product development lifecycle [7]. It supports analysis, animation, and performance optimization of engineering designs. The use of Creo Parametric in the educational process not only enhances students' technical competencies but also fosters design accuracy, reduces development errors, and significantly improves learning efficiency by enabling the creation of high-quality, industry-relevant prototypes [8].

Furthermore, incorporating Creo Parametric into university curricula enables students to simulate real-world engineering problems, experiment with various solutions, and visually interpret the outcomes [9]. Such an approach not only deepens theoretical understanding but also promotes the development of key 21st-century skills, including critical thinking, problem-solving, and digital creativity. Ultimately, fostering such competencies is essential for preparing highly qualified specialists capable of contributing effectively to the evolving demands of modern industry [10].

The integration of computer-aided design (CAD) systems such as Creo Parametric into educational environments has become an essential component of engineering and technical education. The literature emphasizes the growing importance of teaching 3D engineering modeling and prototyping to develop students' spatial thinking, problem-solving abilities, and readiness for industry-standard tools.

2. Literature Review

Several studies highlight that Creo Parametric stands out among CAD systems due to its support for both parametric and direct modeling, which enables a flexible approach to 3D design [11]. This dual capability allows students to explore different modeling strategies and better understand the lifecycle of a product from conception to prototyping [12, 13].

Dakeev [14] notes that Creo's intuitive interface and powerful feature-based modeling tools provide an ideal platform for teaching complex geometry, assemblies, and motion simulation. The software's parametric capabilities reinforce core engineering concepts such as design intent and constraint-based modeling, which are essential for both mechanical and manufacturing disciplines [15].

In the context of project-based learning (PBL), integrating Creo Parametric supports student engagement and collaboration. According to Haghbin [16], implementing PBL with Creo in design courses enhances students' creativity, as they are encouraged to develop and prototype their own designs using industry-grade software. Moreover, the use of 3D printing in conjunction with Creo modeling provides hands-on experience with rapid prototyping and design iteration.

Educational research also points to the value of curriculum alignment with professional engineering practices. Sole [17] found that courses incorporating Creo Parametric contribute to improved job readiness, as students acquire skills that are directly applicable in modern engineering workplaces, especially in sectors such as automotive, aerospace, and manufacturing.

Furthermore, studies underscore the role of certification programs and online learning platforms that offer training in Creo Parametric, such as PTC's official learning resources [18]. These platforms support self-paced learning and can be integrated into traditional coursework or used in blended learning formats [19].

However, challenges remain. Faculty training, licensing costs, and curriculum integration are identified as barriers to widespread adoption [20]. Successful implementation requires institutional support and structured teaching methodologies tailored to varying student skill levels.

In summary, the literature demonstrates that teaching 3D modeling and prototyping with Creo Parametric not only strengthens students' technical competencies but also prepares them for real-world engineering challenges. Continued research is encouraged to explore innovative pedagogical approaches and to measure learning outcomes in diverse educational settings [21].

3. Materials and Methods

The relevance of this work lies in the fact that using the Creo Parametric program can significantly improve the effectiveness of engineering graphics training. It contributes to the overall development of students, taking into account their psychological and physiological characteristics, as well as individual interests and needs, along with the economic conditions in the region [22].

The integration of 3D modeling technologies into the educational process plays a key role in the development of students' cognitive abilities and contributes to a significant increase in their motivation and interest in technical disciplines. Among the most effective tools for teaching computer-aided design (CAD) is the PTC Creo Parametric software (formerly Pro/ENGINEER), which serves as a reliable platform for the creation of precise digital models and quality assurance [23].

Creo Parametric forms the foundation of PTC's product development system, allowing designers and engineers to comprehensively determine the shape, function, and manufacturability of products. Its full associativity ensures that any modifications made to the design are automatically reflected across all dependent components and documentation, regardless of where the change originated. This mechanism increases the reliability of digital models and fosters user confidence, an essential factor when investing in large-scale production systems and resource planning.

The software's network capabilities allow geographically distributed teams to collaborate effectively at all stages of the product life cycle, from concept development to final production. This flexibility aligns with the demands of modern industry and supports educational goals by providing students with exposure to tools used in real-world engineering practices [24].

In contemporary culture, the concept of "3D" has become widespread, often used in marketing strategies and branding, ranging from "3D mascara" to "3D cinema" and "3D panels." However, in technical and academic contexts, "3D" (three-dimensional) refers to the ability to represent objects within a three-axis coordinate system: X, Y, and Z. In contrast to 2D (two-dimensional) representations, 3D models allow for a comprehensive spatial visualization of objects, which is particularly valuable in the fields of mechanical engineering, architecture, and industrial design.

PTC Creo Parametric offers an extensive set of tools for the creation of parametric and direct models, simulation, rendering, and design optimization. Its intuitive interface and integration with other PTC solutions enable an efficient and user-friendly design experience, thereby accelerating the development process while minimizing errors in technical documentation. As a result, the implementation of Creo Parametric in educational institutions not only supports the development of technical competencies but also enhances spatial thinking, creativity, and problem-solving skills among students—preparing them for successful careers in the field of engineering and beyond.

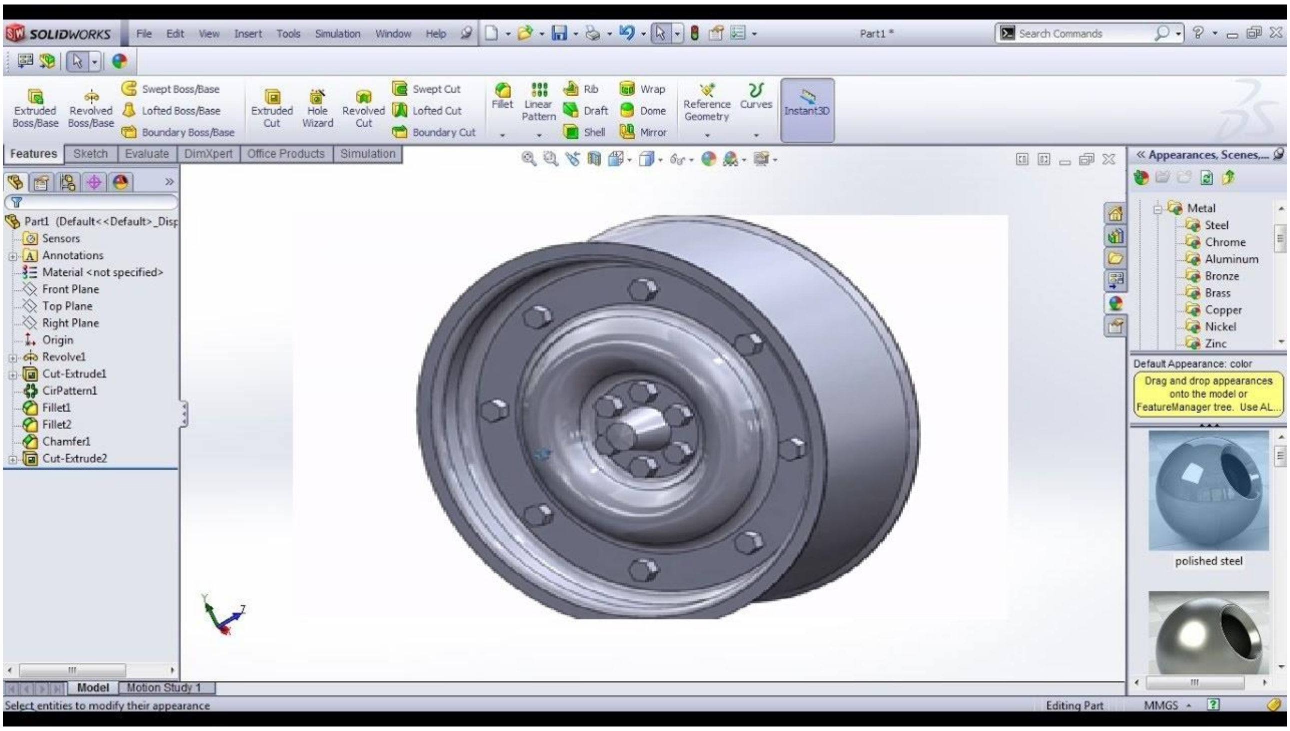

Figure 1.
Modeling of parts in Creo Parametric.

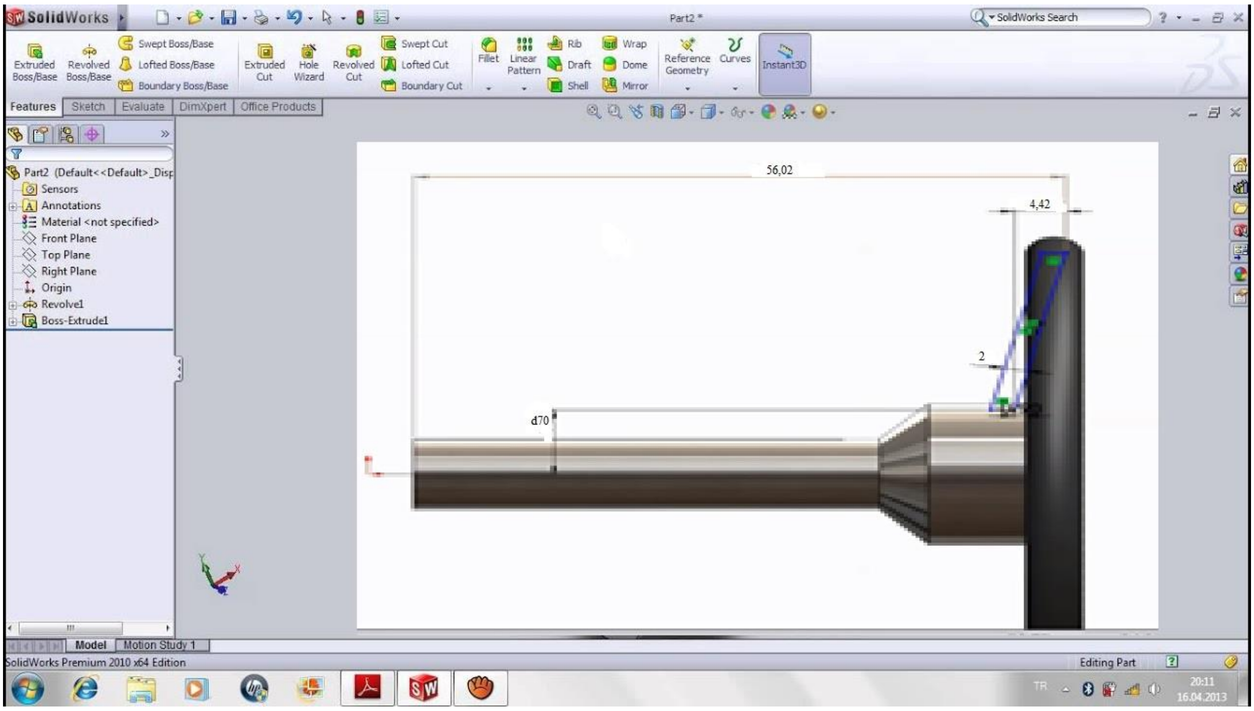

Figure 2.
Modeling of parts in Creo Parametric.

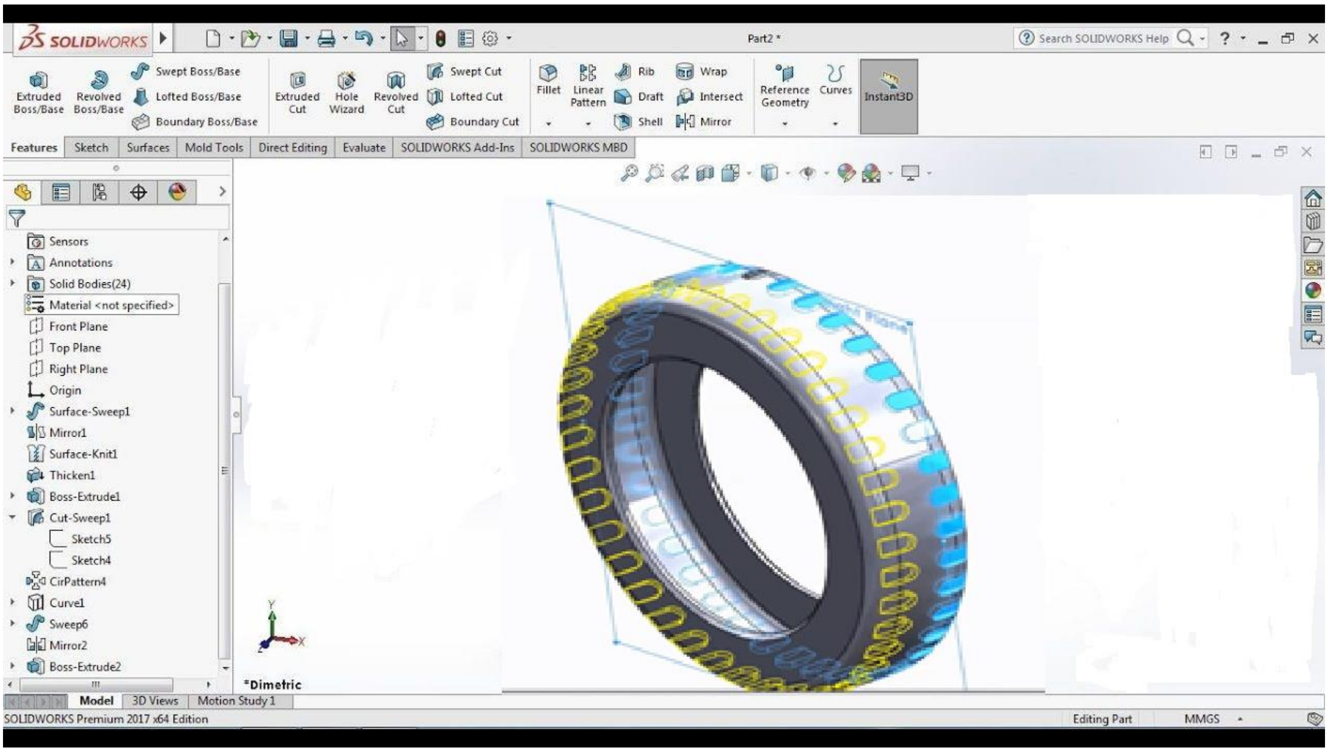

Figure 3.
Modeling of parts in Creo Parametric.

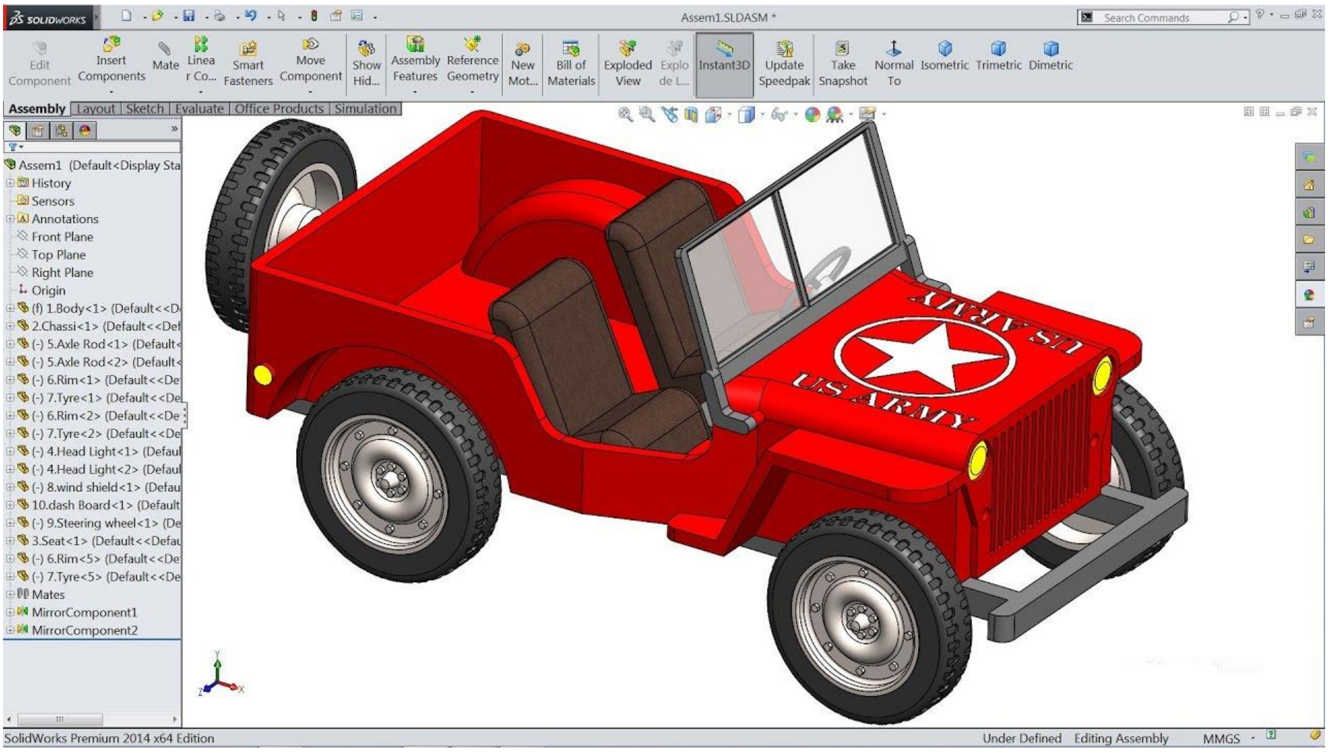

Figure 4.
Modeling of parts in Creo Parametric.

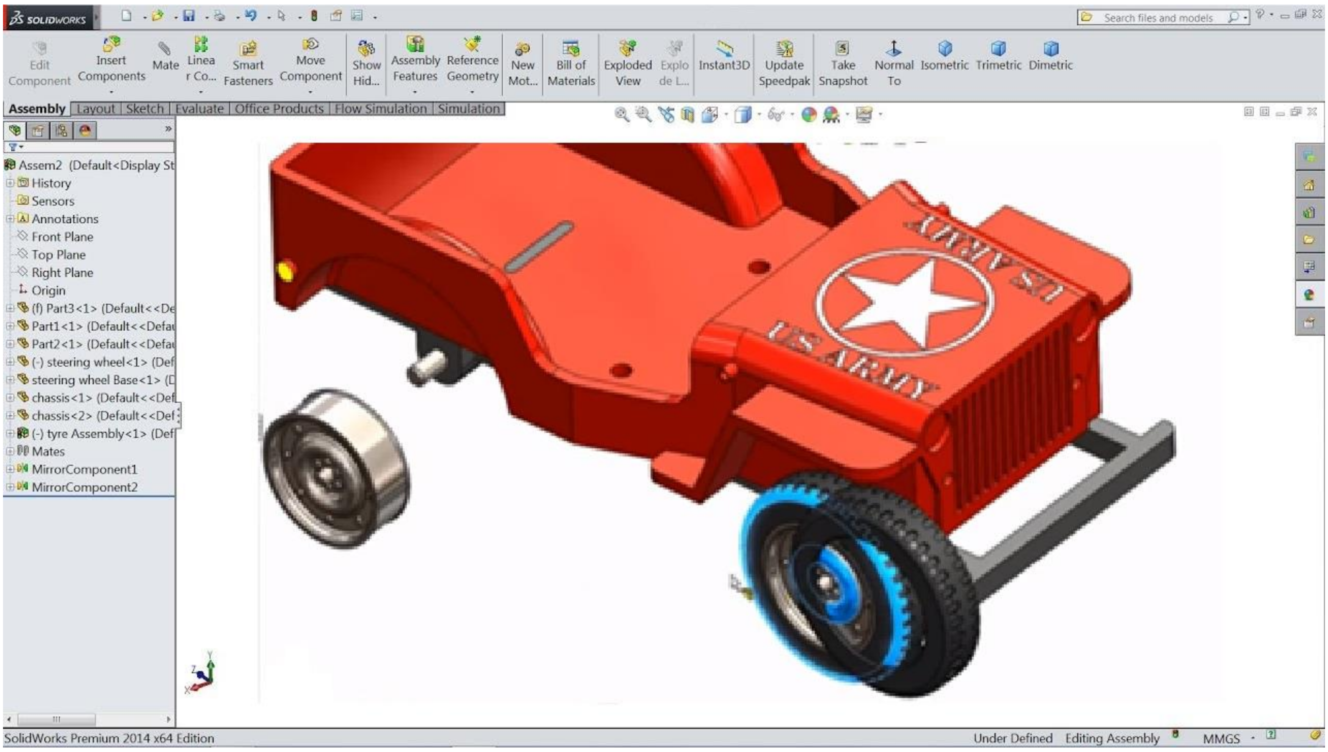

Figure 5.
Obtaining the final design in Creo Parametric.

Creo Parametric provides the ability to create models of parts that include all the necessary information for their subsequent use at various stages of pre-production.

This information is necessary:

1. To prepare a complete set of regular and interactive documentation that meets modern requirements and standards of the ESCD.
2. To analyze and optimize the products being developed.
3. To create tools, accessories, and control programs (UP) for machine tools with numerical control (CNC).
4. For the manufacture of models using rapid prototyping technologies (RP – Rapid Prototyping).

To evaluate the effectiveness of using three-dimensional modeling technologies to improve the quality of education, a pedagogical experiment was conducted. During the experiment, changes in the students' abilities and readiness for creative activity were assessed, as well as their level of knowledge about the theoretical and fundamental foundations of computer modeling.

The experiment included laboratory classes in the discipline "Computer Graphics and Engineering Graphics," which utilized various approaches to organizing students' creative activities when creating prototypes and 3D models. Lectures and practical seminars were conducted in the control and experimental groups.

The control group studied the material on three-dimensional graphics within the framework of traditional methods of teaching information modeling. At the same time, classes in the experimental group were conducted using the capabilities of three-dimensional modeling technologies, which significantly expanded their skills and improved the quality of training.

After the first check, initial data on 55 students were collected, of which two groups were formed: experimental (25 people) and control (30 people). A similar check was carried out after completing the study of the topic.

A control work was chosen as an evaluation tool, including tasks of a reproductive nature, tasks for the application of knowledge and a research task.

The Mann-Whitney criterion was used to test the effectiveness of using 3D technologies in personalized learning and statistical analysis of the reliability of the results of a pedagogical experiment. The results of the control event are presented in Table 1.

Table 1.
The results of the experiment.

The level of innovative thinking	Number of subjects (people)			
	Experimental group (25 students)		Control group (30 students)	
	Before	After	Before	After
High	4	8	5	7
Average	19	16	21	20
Low	2	1	4	3

Hypotheses have been formulated for the application of the criterion:

H_0: The shift in improving educational outcomes after learning 3D modeling technology and getting design practice in a three-dimensional environment is accidental.

H_1: The shift in improving educational outcomes after studying 3D modeling technology and getting design practice in a three-dimensional environment is not accidental.

According to this criterion, it is first necessary to determine the degree of difference in the initial indicators (before the experiment) of the level of knowledge of the subjects in the control and experimental groups. The number of elements in the first sample (experimental group) is 25 people, while in the second sample (control group) there are 30 people. Next, we determine the corresponding critical values according to tables Ucp1 for 0.1 = 236 and Ucp2 for 0.5 = 277. The calculated value of the Mann–Whitney U-test for the initial data is Uemp1 = 351 (Ucp1 < Ucp2 < Uemp), which indicates that the empirical value lies in the zone of significance. Therefore, the null hypothesis that the compared samples match is accepted at a significance level of 0.05, meaning that the initial levels of knowledge in both groups were statistically similar.

Now we apply the same statistical method after the experiment. The empirical value of the Mann–Whitney criterion is Uemp2 = 223. Since Uemp < Ucp1 < Ucp2, this result falls within the zone of insignificance, suggesting a statistically significant difference between the two groups after the pedagogical intervention. Consequently, the reliability of the differences in the compared samples is 95%, which allows us to reject the null hypothesis in favor of the alternative hypothesis (H1).

This outcome supports the assumption that the improvement in the educational results of the experimental group is not accidental but rather a direct consequence of implementing three-dimensional modeling and prototyping in the educational process. The use of modern CAD technologies such as Creo Parametric enhances students' engagement, spatial reasoning, and creative problem-solving capabilities. These findings emphasize the pedagogical effectiveness of 3D modeling tools as a transformative method for developing both theoretical understanding and practical design skills. Furthermore, such tools create an interactive learning environment that supports differentiated instruction and personalized learning trajectories, which are key to preparing future engineers and technical professionals for the demands of Industry 4.0.

4. Results and Discussion

The pedagogical experiment aimed to evaluate the effectiveness of using 3D modeling technologies, specifically Creo Parametric, in improving students' innovative thinking and readiness for creative engineering tasks. The study involved 55 students, divided into an experimental group (25 students) and a control group (30 students), with both groups initially showing comparable levels of knowledge and skills. After a series of laboratory classes, lectures, and practical seminars differently organized for each group the results demonstrated notable distinctions. While the control group followed traditional instructional methods, the experimental group utilized the advanced features of Creo Parametric, which included parametric and direct modeling, associative updates, and tools for creating interactive documentation and prototypes. As shown in Table 1, the number of students with a high level of innovative thinking increased from 4 to 8 in the experimental group, while the control group only showed a modest rise from 5 to 7. Students in the experimental group also saw a slight decrease in those with low-level thinking (from 2 to 1), suggesting improved understanding and engagement. To ensure statistical rigor, the Mann–Whitney U test was applied. The pre-experiment U value (Uemp1 = 351) exceeded the critical value (Ucp = 277), indicating no significant difference between the initial states of the two groups. However, the post-experiment value (Uemp2 = 223) fell below the critical threshold, signifying a statistically significant improvement in the experimental group's performance at a confidence level of 95%. These results support the alternative hypothesis (H1), confirming that the observed improvements in the experimental group were not accidental but directly related to the implementation of 3D modeling technologies. The hands-on use of Creo Parametric, which integrates modeling, analysis, and prototyping, fostered the development of cognitive and practical skills that are crucial for modern engineering education. Moreover, the findings align with existing literature, which emphasizes the value of 3D CAD tools in enhancing students' design thinking, technical proficiency, and motivation (e.g., Raghavan & Kumar, 2019; Chen et al., 2021). By working with digital models in a realistic design environment, students gained a clearer understanding of spatial relationships, manufacturing constraints, and product functionality.

5. Conclusion

Teaching 3D engineering modeling and prototyping in the Creo Parametric system in educational institutions is an important step towards training specialists who are able to work effectively in modern industrial conditions. The analysis shows that Creo Parametric, due to its flexibility and versatility, offers unique features that make it the preferred tool in mechanical engineering. Comparison with other CAD systems such as NX and SolidWorks highlights Creo's advantages in combining parametric and direct modeling, as well as in integration with other software products.

To successfully master 3D modeling, it is necessary to pay attention not only to the technical aspects of working in CAD systems but also to understand the specifics of their application in various industries. Effective training of future specialists requires a comprehensive approach that includes practical skills, theoretical knowledge, and adaptation to rapidly changing market requirements. The integration of Creo Parametric into academic programs will provide students with competitive advantages and prepare them for a successful career in the field of mechanical engineering and related fields.

Moreover, the pedagogical results obtained during the experimental part of this study confirm the positive impact of 3D modeling technologies on the development of students' creative and cognitive abilities. The use of Creo Parametric not only increases motivation and engagement in the learning process but also fosters critical thinking, problem-solving skills, and engineering intuition. The associative nature of digital models enables iterative development and cross-functional collaboration, which are core competencies in modern design and production environments.

Given the continuous evolution of engineering technologies, it is essential to revise and update educational content regularly, aligning it with current industrial standards and digital transformation trends. Institutions that incorporate advanced CAD tools like Creo Parametric position themselves at the forefront of educational innovation and ensure the professional relevance of their graduates in the global job market.

References

[1] R. Fujimoto, C. Bock, W. Chen, E. Page, and J. H. Panchal, *Research challenges in modeling and simulation for engineering complex systems*. Cham: Springer International Publishing, 2017.

[2] P. Doungmala and T. H. Thai, "Investigation into the application of image modeling technology in the field of computer graphics," *International Journal for Applied Information Management,* vol. 3, no. 2, pp. 82-90, 2023.

[3] N. F. Dana and D. Yendol-Hoppey, *The reflective educator's guide to classroom research: Learning to teach and teaching to learn through practitioner inquiry*. California, USA: Corwin Press, 2009.

[4] G. Khan, H. Maraha, Q. Li, and K. Pimbblet, "A brief review of recent advances in AI-Based 3D modeling and reconstruction in medical, education, surveillance and entertainment," presented at the 2024 29th International Conference on Automation and Computing (ICAC), IEEE, 2024.

[5] J. P. McIntire, P. R. Havig, and E. E. Geiselman, "Stereoscopic 3D displays and human performance: A comprehensive review," *Displays,* vol. 35, no. 1, pp. 18-26, 2014.

[6] J. C. Roberts, P. W. Butcher, and P. D. Ritsos, "One view is not enough: Review of and encouragement for multiple and alternative representations in 3d and immersive visualisation," *Computers,* vol. 11, no. 2, pp. 1-20, 2022.

[7] F. Soulas, "Digital image correlation (DIC) for vibration analysis," *Futurities—Spring 2023,* pp. 33-35, 2023.

[8] P. Sahoo and S. K. Das, *Manufacturing engineering education—Indian perspective. In Manufacturing engineering education*. Oxford, United Kingdom: Chandos Publishing, 2019.

[9] G. Guo, "Enhancing project-based manufacturing education with integrated engineering software tools," *Computer Applications in Engineering Education,* vol. 33, no. 2, p. e70012, 2025.

[10] P. Fitsilis, P. Tsoutsa, and V. Gerogiannis, "Industry 4.0: Required personnel competences," *Industry 4.0,* vol. 3, no. 3, pp. 130-133, 2018.

[11] A. Lindsay, "Industrial parametric CAD model efficiency: How complexity and quality characteristics influence recommended modelling strategies," Doctoral Dissertation, Loughborough University, 2022.

[12] V. Viswanathan, O. Atilola, J. Goodman, and J. Linsey, "Prototyping: A key skill for innovation and life-long learning," in *2014 IEEE Frontiers in Education Conference (FIE) Proceedings, IEEE*, 2014, pp. 1-8.

[13] Z. Zulpykhar, M. Ongarbayeva, A. Tungatarova, and Z. Altynbekova, "On-line examinations with proctoring: features, students' preferences and related factors, academic honesty," *World Trans. on Engng. and Technol. Educ,* vol. 21, no. 4, pp. 287-292, 2023.

[14] U. Dakeev, *Creo parametric modeling with augmented reality*. Hoboken, NJ, USA: John Wiley & Sons, 2023.

[15] C. H. Shih and B. Anderson, "A design/constraint model to capture design intent," in *Proceedings of the Fourth ACM Symposium on Solid Modeling and Applications*, 1997, pp. 255-264.

[16] N. Haghbin, "Revolutionizing mechanical engineering one-credit laboratory courses: A project-based learning approach," presented at the ASEE North East Section Conference Proceedings. American Society for Engineering Education, Philadelphia, PA, USA, 2024.
[17] M. Sole, "How to teach mechanical engineering design using industry methods while still assessing to university criteria," Doctoral Dissertation, University of Derby, United Kingdom, 2023.
[18] M. Gumbo, *Development of a comprehensive design handbook for enhancing mechanical engineering practices for a company (Unpublished manuscript)*. XYZ Engineering Ltd: Johannesburg, South Africa, 2024.
[19] E. Ebbini, *Enhancing collaborative and self-paced learning in traditional and distance education settings. In Higher education in the Arab world: E-learning and distance education*. Cham: Springer Nature Switzerland, 2023.
[20] W. W. Porter and C. R. Graham, "Institutional drivers and barriers to faculty adoption of blended learning in higher education," *British Journal of Educational Technology,* vol. 47, no. 4, pp. 748-762, 2016.
[21] A. Peterson, H. Dumont, M. Lafuente, and N. Law, *Understanding innovative pedagogies: Key themes to analyse new approaches to teaching and learning (No. 172)*. Paris, France: OECD Publishing, 2018.
[22] N. Karelkhan, D. Meiirbekkyzy, and P. Gapbarova, "High-performance parallel computing on the Param Bilim supercomputer in higher education," *World Transactions on Engineering and Technology Education,* vol. 22, no. 2, pp. 137–143, 2024.
[23] A. Orynbayeva, N. Shyndaliyev, and A. Aripbayeva, "Improving statistical methods of data processing in medical universities using machine learning," *World Transactions on Engineering and Technology Education,* vol. 21, no. 1, pp. 58-63, 2023.
[24] M. Serik, G. Nurbekova, M. Mukhambetova, and Z. Zulpykhar, "The educational content and methods for big data courses including big data cluster analysis," *World Transactions on Engineering and Technology Education,* vol. 20, no. 3, pp. 203–208, 2022.