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Modern approach to computer modeling of functional 3d objects in the professional training of future engineers and vocational education teachers

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Abstract: This article examines the features of computer modeling of functional 3D objects using the SolidWorks software suite, which is an integral component in the training of future engineers and vocational education teachers. The SolidWorks software suite provides tools not only for creating three-dimensional models but also for analyzing the mechanical properties of parts and visualizing the technical condition of objects. This enables future engineers and vocational education teachers to better understand the principles of designing and analyzing complex part structures. A step-by-step algorithm for computer modeling has been developed, from creating a basic sketch to completing a three-dimensional model of a functional object. It has been established that the computer modeling process allows for the selection of appropriate tools and commands for creating geometric transformations of objects and setting parameters. This ensures high accuracy in constructing a computer model according to its geometric parameters. It has been established that the modern approach to computer modeling in the educational process demonstrates the implementation of innovative technological solutions to improve the quality of training in higher education institutions. It has been determined that the proposed approach will not only help future engineers and vocational education teachers develop practical skills but also contribute to a deeper understanding of engineering concepts.
Keywords: *Computer modeling, Digitization of education, Future engineers and vocational education teachers, SolidWorks, STEM education, STEM projects, STEM technologies.*

1. Introduction

The modern labor market is witnessing an increased demand for specialists with a broad range of skills capable of effectively responding to new challenges. These requirements are relevant across various sectors, from information technology to the financial industry, where employers seek professionals who can analyze large volumes of information, make informed decisions, and work efficiently in teams. According to "The Future of Jobs Report 2023," the most sought-after skills include proficiency with new technologies, critical thinking, productive communication, and a readiness for continuous learning. The report also emphasizes the importance of adaptability and flexibility, as rapid technological changes continuously modify professional processes and employee requirements [1].

The Ukrainian higher education system is actively adapting to contemporary challenges aimed at training highly qualified specialists. This need is a response to the socio-economic processes observed in the country. The importance of training qualified personnel is heightened by global technological changes that require deep knowledge and skills in the field of computer modeling of functional 3D objects. The training of engineers and vocational education teachers in modern conditions involves not only traditional education but also mastering advanced modeling and design techniques.

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Significant changes in the budgeting of the educational sector, especially during the martial law in Ukraine, have accelerated the process of rethinking educational approaches. The emigration of qualified scientists from the country stimulates the renewal of the educational system, oriented towards global scientific and intellectual standards. This necessitates the implementation of new teaching and research methods, particularly in the area of computer modeling.

The educational process now includes comprehensive training that combines theoretical knowledge and practical skills, meeting the demands of the modern labor market. This encompasses the development of professional and general competencies, such as the ability to learn, critical thinking, programming, and creativity. Educators who employ innovative methodologies play a key role in shaping the personality and professional qualities of future specialists capable of working effectively in diverse conditions [2].

Changes in the educational process also include the integration of interdisciplinary approaches and the freedom to choose educational trajectories, which fosters the development of students' individual potential. This reflects global educational trends and supports Ukraine's competitiveness on the international level.

The modern training process for future engineers and vocational education teachers requires appropriate skills and abilities in computer modeling and visualization of functional 3D objects. It encompasses relevant stages that play a key role in the preparation and formation of modern and competitive highly qualified specialists. This allows students to thoroughly assimilate the theoretical course material and apply innovative software suites for computer modeling, investigating both the mechanical properties of parts and the visualization of complex geometric bodies, including functional 3D objects. Therefore, it is advisable for future engineers and vocational education teachers to apply computer modeling of functional 3D objects to acquire skills and abilities during the design process [3].

2. Literature Review

Given that professional activities in the modern labor market require not only deep technical knowledge but also the ability to convey this knowledge to future specialists, it is important to integrate practical skills in modeling and visualizing functional 3D objects into the educational process. This not only enhances the understanding of the technical aspects of engineering but also improves the effectiveness of pedagogical activities, allowing future specialists to successfully adapt to the demands of a high-tech labor market [4].

In the study [5], a new approach to the functional classification of simple objects in the form of 3D images is proposed. Based on training, a multi-level hierarchical description of objects is constructed, which allows for the use of various reasoning approaches through annotations. This approach employs plausibility rules that enable the construction of radial functions from histograms of object instances. The approach proposed by the authors has been tested on a significant number of real objects, achieving high classification accuracy with small training sets. However, the study presents a method for segmenting 3D images that does not allow for the analysis of the mechanical properties of the object being studied or observed.

The work [6] highlights the main tasks faced by students in higher education institutions under modern learning conditions, requiring a special approach. This approach is based on the application of a unified educational system to solve complex disciplinary tasks. The authors propose various interdisciplinary connections related to information and communication technologies and systems thinking. In this regard, statistical information on the performance of a group of mechanical engineering students was collected. Multiple regression analysis was used to process the statistical information, which allowed for the identification and evaluation of the positive and negative qualities of systems thinking. However, the study did not focus on the modern approach and features of student learning using the creative criterion of critical thinking. This criterion combines flexibility, originality, and productivity, enabling the consideration of new methods and approaches related to the design of components and parts for both the mechanical engineering and transportation industries, as well as other sectors of the national economy.

In the research [7], the authors analyze the contemporary challenges faced by vocational education. Among the key issues are globalization, digital transformation, and the constantly changing demands of the labor market. This requires educational institutions to adapt their programs and enhance the qualifications of teachers to meet new realities. The emphasis is placed on the importance of implementing innovative approaches to the training of future specialists, especially considering rapid technological changes and the internationalization of the professional environment.

The approaches proposed in the work [8] focus on methods for preparing STEM discipline teachers to work with students in a distance learning environment. The authors explore both technical and methodological aspects of this process, including the use of digital platforms and interactive technologies. Significant attention is given to the issue of equal access to distance education and the importance of developing self-regulation in students during their studies.

The article [9] discusses an innovative project that uses fuzzy logic for the segmentation of vehicle images. This research demonstrates the effectiveness of combining STEM technologies with fuzzy logic in the educational process, allowing future engineers and teachers to master modern technologies and develop critical thinking. This approach promotes the integration of technological projects into educational programs, stimulating students' engineering creativity.

The importance of cognitive and metacognitive processes for the development of the creative potential of future educators is highlighted in the study [10]. The authors emphasize the significance of self-reflection and the ability to analyze one's own learning processes as key elements in teacher preparation, enabling them to work effectively in a changing educational environment.

The article [11] is dedicated to the analysis of didactic principles for teaching 3D printing technologies. The authors stress the importance of interdisciplinary approaches to education, which allow for the development of both creative and technical skills in students. Integrating 3D printing into the educational process prepares students for the modern labor market challenges, where digital technologies play a crucial role.

The impact of STEM technologies on the development of pedagogical skills in students is examined in the study [1]. The authors note that the application of STEM technologies stimulates student interest while simultaneously developing their technical and analytical abilities. This contributes to the improvement of education quality and student engagement in the learning process.

The importance of implementing STEM education in the training process for future engineers and educators is highlighted in the study [12]. The authors argue that integrating practical knowledge and modern technologies into educational programs is essential for preparing specialists capable of meeting the demands of the contemporary labor market.

The reviewed scientific articles demonstrate the importance of innovative approaches and digital technologies in the training of specialists across various fields. The implementation of STEM education, digital tools, and cognitive teaching methods fosters the development of critical thinking, creativity, and technical skills, which are crucial for adapting to the modern labor market requirements. Additionally, the studies emphasize the necessity of equal access to the latest educational technologies and the importance of professional training for educators to work in a constantly changing educational environment.

Current global practice shows that mechanical and architectural design is a multifunctional process that requires the training of highly qualified specialists. Therefore, in the work [13], the authors pay special attention to the need for an interdisciplinary approach to teaching future engineer's architectural design. This approach allows for mastering the methodologies of elective courses and acquiring relevant knowledge, skills, and abilities in construction, technological, and structural directions. This approach is proposed at the Warsaw University of Technology based on the interactive teaching method "Case Study". It aims to direct the learning process towards the real conditions of professional activity. However, the authors did not address the basics of designing functional units that operate under extremely complex conditions and require special approaches and methods for student training.

The increase in the capacities of factories, plants, and traction power of units necessitates the search for alternative sources of electricity. Thus, the study [14] is aimed at examining a STEM project for future mechanical engineering specialists, which involves various experiments to obtain electrical energy – wind, solar, and water. The experimental research created significant data arrays used for student training, demonstrating improved comprehension of lecture and theoretical material in professional disciplines. Therefore, the application of STEM projects is also proposed for the design of functional units in the mechanical and railway industries. This would significantly enhance the use of STEM education for better assimilation of theoretical and practical training material.

Various aspects of implementing STEM education and executing STEM projects are discussed in the works [12, 15-18], which also confirm the effectiveness and relevance of STEM education. Participation in STEM projects fosters students' creative abilities, the importance of which is described in the study [19]. The effectiveness of education can be enhanced by predicting students' educational achievements using data mining [20, 21] and machine learning methods [22].

In the modern labor market, there is a demand for skills related to the practical application of data mining [23, 24], artificial intelligence [25-28], computer graphics, and modeling. These skills are particularly important for future engineers and vocational education teachers, who also extensively use methods of digital image processing, computer modeling, and object visualization in their professional activities. Among the methods of digital image processing, filtering [29, 30], edge detection [31, 32], segmentation [9, 33, 34], and contrast enhancement [35] are applied. Computer modeling methods allow for the accurate calculation of object operating modes [36, 37]. For the visualization of objects, especially those with complex geometric shapes, the use of three-dimensional graphics [38], augmented reality [39], and extended reality [40] is effective.

To address the challenges of training highly qualified engineering and pedagogical specialists in higher education institutions, modern techniques, approaches, methods, and teaching tools are employed, enabling students to acquire professional skills [41]. For example, during the training of students in fields related to transportation and services, specifically railway transport, students master professional and specialized disciplines that provide them with qualified skills and abilities. During their studies, students pay significant attention to computer modeling, analysis of visualization, and test information about rolling stock components, as well as the dynamic processes occurring during movement [42, 43]. The use of modern computer systems such as SolidWorks, AutoCAD, CorelDRAW, Visio, and others during training allows engineering students to successfully apply them to solve practical tasks. Specifically, working with the SolidWorks software suite enables the construction of functional 3D objects with complex geometric shapes that operate under significant dynamic and static loads [44]. Additionally, the use of SolidWorks allows for theoretical studies on modeling the loads acting on rolling stock components during their design, operation, and determination of residual life.

The analysis of literature sources [1, 4–44] indicates that the issue of acquiring competencies in the design and computer modeling of functional 3D objects using the SolidWorks software suite is relevant. In particular, further research into the strength characteristics and visualization of complex geometric shapes is important, as these aspects require expanded scientific understanding and the improvement of application methodologies.

3. Purpose and Tasks of the Research

The objective of this research is to explore contemporary approaches to computer modeling of functional 3D objects in the professional training of future engineers and vocational education teachers. To achieve this objective, the following tasks must be addressed:

- Outline the general aspects of the use of 3D modeling;
- Analyze the graphical representation of a functional 3D object;
- Examine the specific features of computer modeling in the construction of a functional 3D object.

4. Materials and Methods

4.1. General Aspects of the Use of 3D Computer Modeling

The process of computer modeling gains particular significance due to its use as a core component of pedagogical activities and the creation of educational projects. The concept of "modeling" pertains to the pedagogical lexicon from the technical domain and requires scientific substantiation, the establishment of norms, and the regularities of functioning within the educational system.

The term "modeling" is defined as "a method of studying phenomena and processes based on the substitution of a specific research object with another, similar one – a model" [45]. In a broad sense, "modeling is the process of adequately reflecting the simplest properties of the studied object or phenomenon with the precision necessary for practical needs" [46]. Thus, "modeling is the process of depicting the research object with a similar model, conducting experiments with it to obtain information about the research object" [46].

In turn, "computer modeling is the creation of an object or phenomenon using computer technology and mathematical, physical, or logical systems. The result of modeling is computer models, which can be presented in 2D or 3D formats; they can be static or gamified (with animation elements)" [47].

In the professional training of future specialists in engineering and vocational education, it is advisable to perform modeling and visualization of complex 3D objects using functional objects designed to perform specific tasks or functions. Modeling functional 3D objects facilitates better assimilation of abstract mathematical concepts and stimulates logical and spatial thinking. During project work, future engineers and teachers learn to use 3D modeling tools, which is an essential competency in many modern professions [47].

The training process for students in engineering and vocational education specialties in modeling and visualizing functional 3D objects encompasses relevant stages that play a key role in preparing and forming modern and experienced high-quality specialists. This enables future engineers and teachers to thoroughly assimilate the theoretical course material and allows for the practical application of innovative software suites for computer modeling, investigating both the strength characteristics and visualization of complex geometric bodies, including functional 3D objects.

One of the stages of modeling functional 3D objects is the preliminary study of general and professional disciplines, which allows the student to have a conceptual visual representation of the object being subjected to computer modeling. Another important factor is that the student must know the mechanical properties of the object being designed, its operating conditions, and the nature of the static and dynamic loads acting on it.

4.2. Analysis of the Graphical Representation of Functional 3D Objects

The subject of modeling is the non-rotating brake shoe, a complex functional object that is part of the brake lever transmission (BLT) of the 18-100 model freight car bogie [48, 49]. The non-rotating brake shoe absorbs the load developed by the brake cylinder, which is transmitted through the BLT system of rods and levers to the brake shoe, which then applies braking to the freight rolling stock [50, 51].

The non-rotating brake shoe is characterized by its complex geometric shape. It consists of upper and lower ribs that firmly connect the support surface. The central part of the non-rotating shoe has a slot for installing a pendulum suspension, allowing it to move freely during braking. The support surface and ribs of the non-rotating brake shoe are connected to the faces of a quadrilateral slot designed to mount it on the triangle beam. The entire structure of the non-rotating brake shoe is rigidly connected by at least one stop, which is made in the form of a plate or rod and is intended to limit the rotation of the shoe relative to its pendulum suspension [52, 53].

Since the non-rotating brake shoe is a functional object that absorbs and transmits significant loads, it is essential to focus on its design stages for students. The study of the object model is carried out using the SolidWorks software suite, which allows for modeling, analysis of the mechanical properties of parts, and visualization of the technical condition of the object [54, 55].

4.3. Features of Computer Modeling in the Construction of a Functional 3D Object

The modeling process in SolidWorks begins with sketch creation, which starts with selecting the construction plane where the two-dimensional sketch will be built [56]. As is known, models of varying complexity can be constructed in different sequences and by various methods. The choice of construction method depends on the analysis of the build, the functional properties of the model, and the developer's experience in technical drawing.

During sketch creation, a full set of geometric tools and editing operations is available. There is no need to immediately adhere to precise dimensions; it is sufficient to approximate the sketch configuration. Later, if necessary, the developer can change any dimension value and apply constraints that limit the mutual arrangement of lines, arcs, circles, etc.

Based on the analysis of the geometric shape of the non-rotating brake shoe, it can be optimally constructed in two ways at the initial stage:

1. Create the profile of the central part of the shoe by selecting the horizontal projection plane;
2. Create the profile of the shoe contour by selecting the frontal projection plane.

For a more prepared audience of students, the first option can be proposed, while the second option is suitable for beginners. The advantage of the second method is the accessible transitions from operation to operation with fewer steps.

The process of constructing the contour model of the non-rotating brake shoe in SolidWorks begins with selecting the model's position in the coordinate system [49, 57]. To do this, click the left mouse button to select "FrontPlane". This will place the model in the XY coordinate system to the right. To create the contour profile, we will use a series of primitives: "Line", "Circle", "Point", "Center Arc", and operations "Trim Entities", "Sketch Fillet". During the construction of the non-rotating brake shoe model, SolidWorks displays numerical values on the screen. Without releasing the left mouse button, select the desired value, press "Enter", and release the left mouse button. Another option is to assign the specified dimensional values to the already constructed primitives using the "Smart Dimension" function.

To do this, activate the "Smart Dimension" function. Move the cursor to the desired side of the primitive, click the left mouse button, and without releasing it, drag the resulting dimension to the required distance. Then, adjust the model by entering the necessary numerical values, thereby applying dimensions to the geometric construction. To exit or change the operation, click the green checkmark or the "Ok" button.

After completing the graphical constructions, ensure that dimensions are applied to all parts of the profile (Figure 1). The color of the lines will change from blue to black.

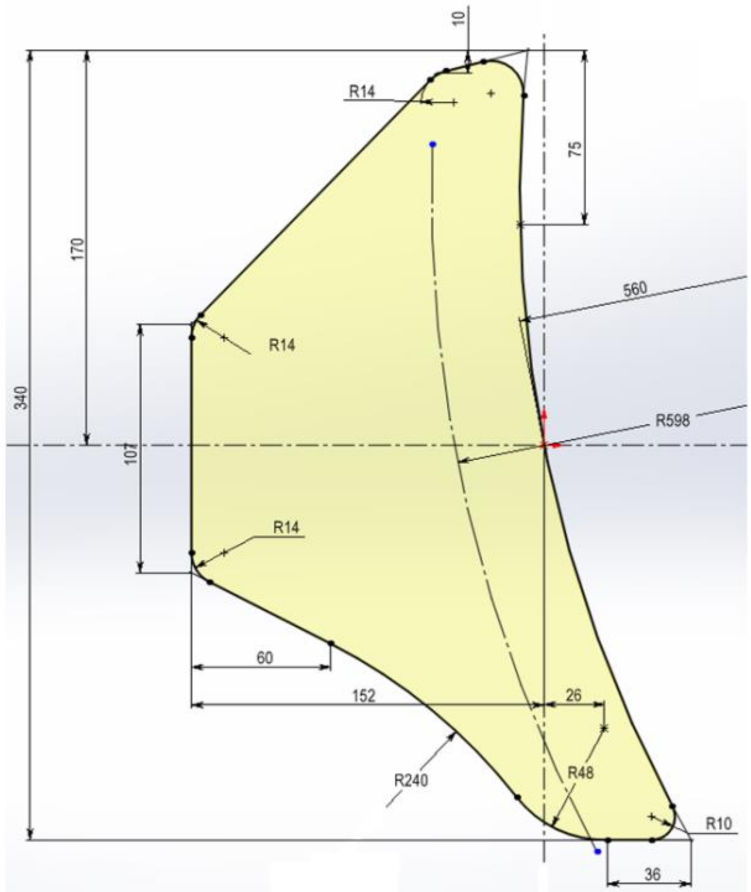

Figure 1.
Dimensional parameters of the contour diagram of a non-rotating brake shoe.

Pressing the "Close Dialog" button on the left side of the screen or exiting the sketch on the right side of the screen completes the process of two-dimensional constructions. The red cross closes the operation without saving the actions performed.

After completing the formation of the diagram, we proceed to the "Features" panel, which activates the operations for creating volumetric figures. For this diagram, we apply the "Extruded Boss/Bose" operation and respond to the extrusion depth query by entering a numerical value. The process of forming a solid volumetric image of the contour of the non-rotating brake shoe is completed.

Next, a rectangular hole needs to be created on the constructed contour of the non-rotating brake shoe for its attachment to the triangle. The sequence of actions includes the following intermediate operations: constructing the diagram (Figure 2a) followed by extruding the rectangular hole and corner semicircles (Figure 2b, 2c, 2d).

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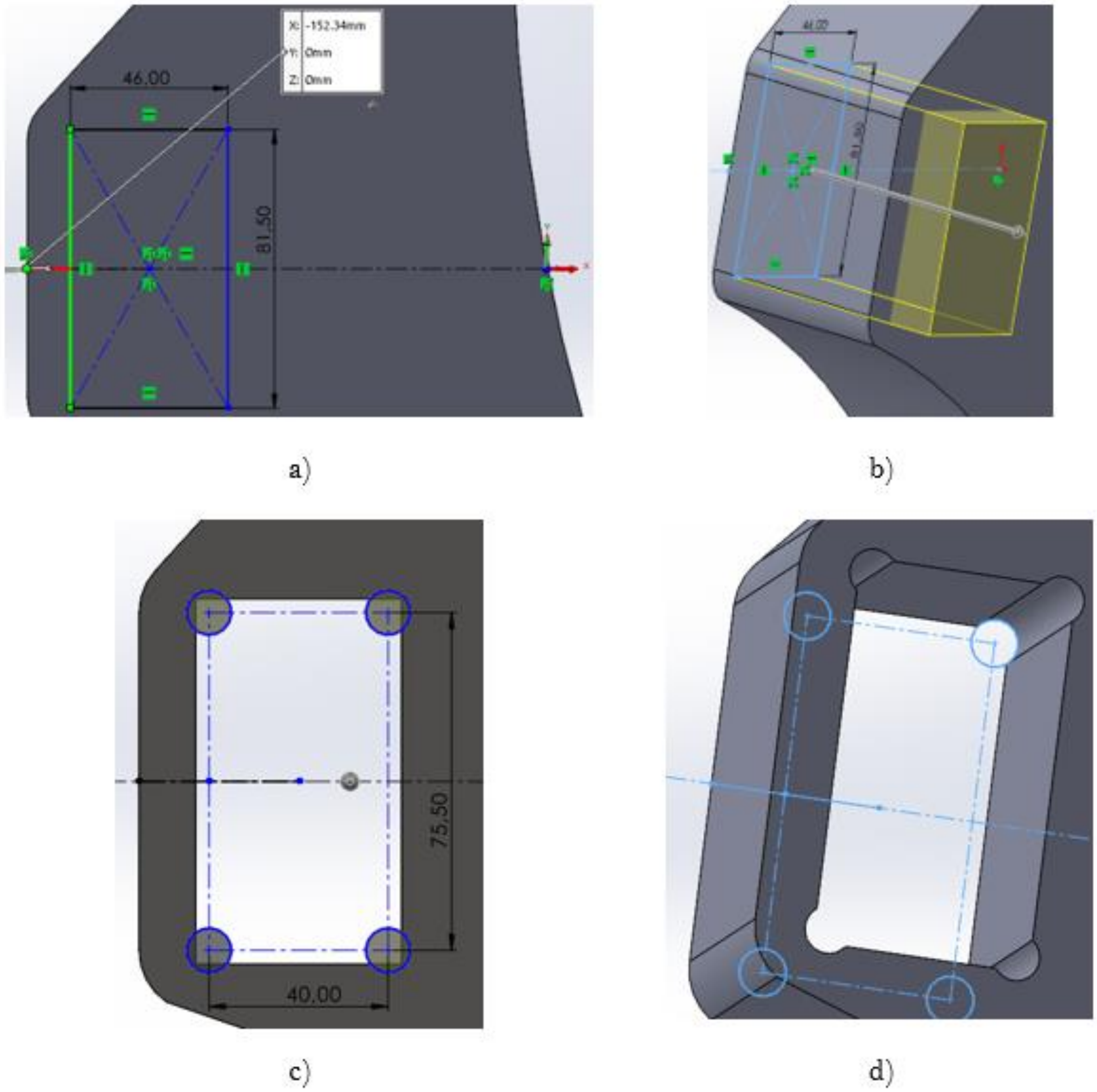

Figure 2.
Operations for forming a mounting hole for a non-rotating brake shoe on the triangle.

The next step involves forming the right part of the non-rotating brake shoe, which includes the hole for the pendulum suspension, the slot for the shoe lug, and the mounting holes for the shoe and the brake shoe guide [57].

This process is divided into the following actions: constructing the diagram of the hole and slot (Figure 3a), their mirror reflection (Fig. 3b), and cutting to the specified distance (Figure 3c).

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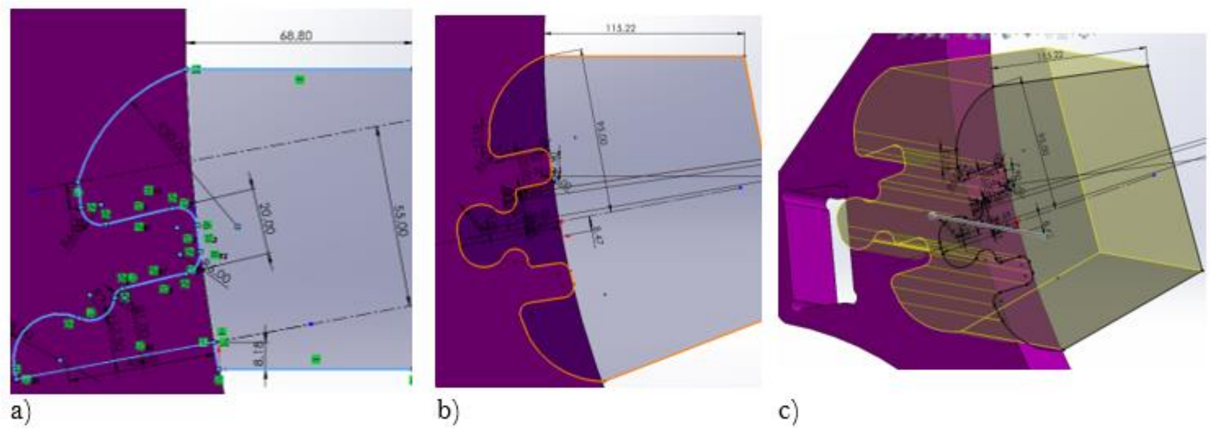

Figure 3.
Process of constructing the hole and slot of the non-rotating brake shoe.

The subsequent steps involve constructing the brake shoe guide and the holes for its mounting points.

A distinctive feature of constructing the brake shoe guide is the operation of creating auxiliary planes perpendicular to the shoe guide ("Plane1" and "Plane2"). The creation of auxiliary planes is performed in the following sequence: a) In the "Reference Geometry" tab, activate the "Plane" option; b) In the "Feature Manager" panel, which opens in the "First Reference" line (Fig. 4a), mark the line on the object where the plane will be constructed; c) In response to the "Second Reference" query from the Feature Manager, activate the shoe guide (Figure 4b).

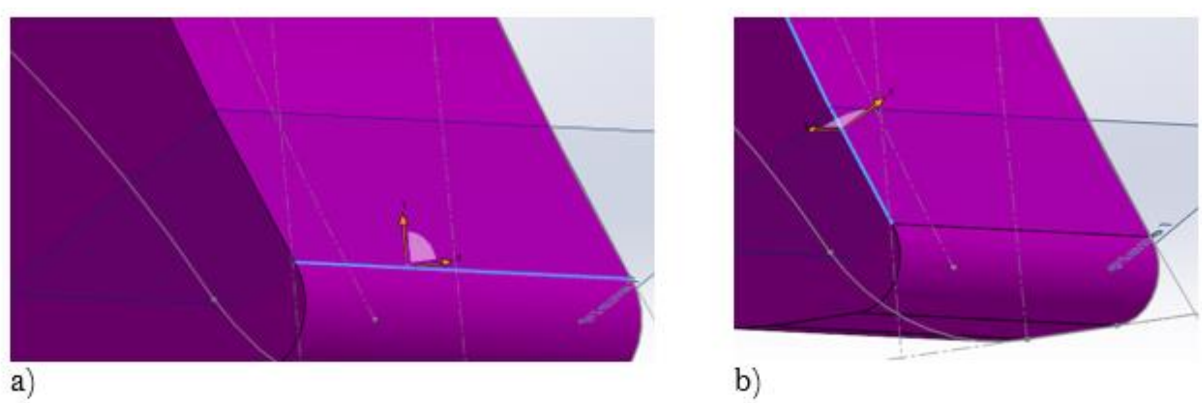

Figure 4.
Operation of creating auxiliary planes for the non-rotating brake shoe.

On the created auxiliary planes, we construct the profiles of the holes in the lower and upper parts of the shoe and apply the "Sweep Cut" operation for extrusion towards the central part of the object and the "Cut-Extrude" operation for outward extrusion (Figure 5). The use of two extrusion operations is due to the fact that the line for creating the auxiliary plane is not at the end of the object.

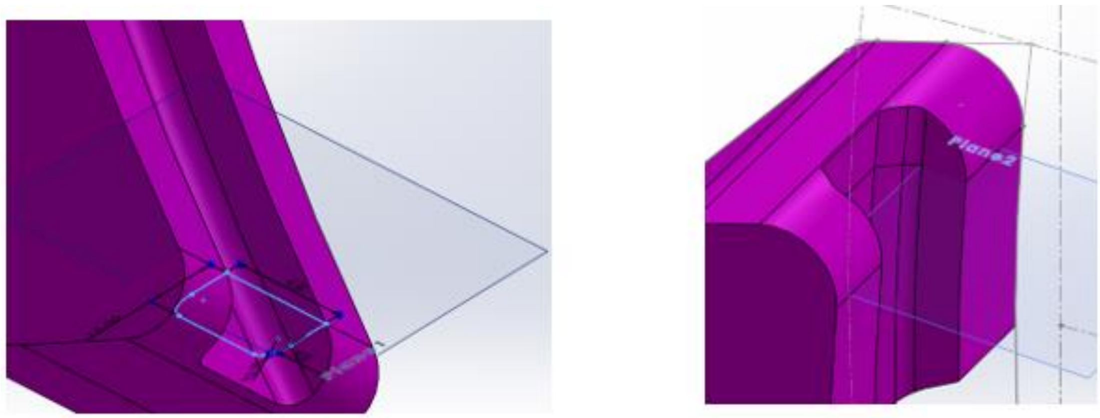

Figure 5.
Operation of creating mounting points for the brake shoe on the non-rotating brake shoe model.

The completion of the construction at this stage is confirmed by pressing the "Ok" button.

Next, the construction of the brake shoe mounting points, which are rectangular holes with rounded corners, is carried out [54, 58]. A distinctive feature of these constructions is the use of the side of the part as the plane for constructing the profile. Therefore, the following steps are required:

- Activate the Sketch mode for two-dimensional constructions;
- Select the part of the model where the profile is to be constructed (Figure 6a);
- Activate the "Midpoint Line" primitive and construct a rectangle with the required dimensions, then apply the geometric dimensions to it;
- Use the "Sketch Fillet" operation to round the corners of the rectangle and close the dialog box;
- Apply the "Extrude" operation to the constructed profile (Figure 6b).

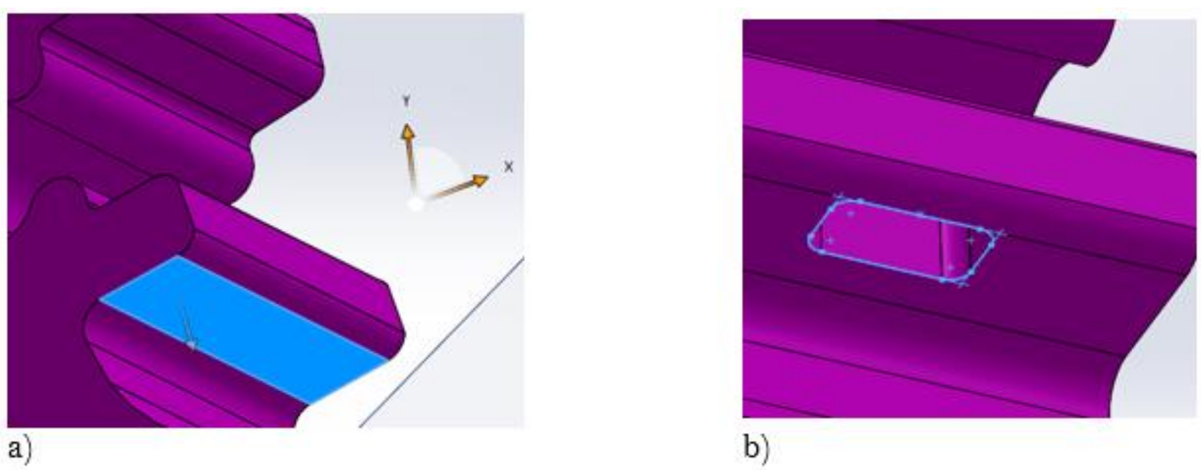

Figure 6.
Similarly, the same steps need to be performed to create the second mounting hole for the brake shoe.

The final stage of constructing the non-rotating brake shoe model is a procedure aimed at reducing its weight without compromising its strength. This is a technological operation involving the cutting of a part of the non-rotating brake shoe body that does not participate in technical operations [59].

The next design stage is to create the cutout zones in the shoe body, which should be performed in the following sequence:

a) Create a profile in the upper part of the shoe, applying dimensions that are referenced to the model's contour (Figure 7);

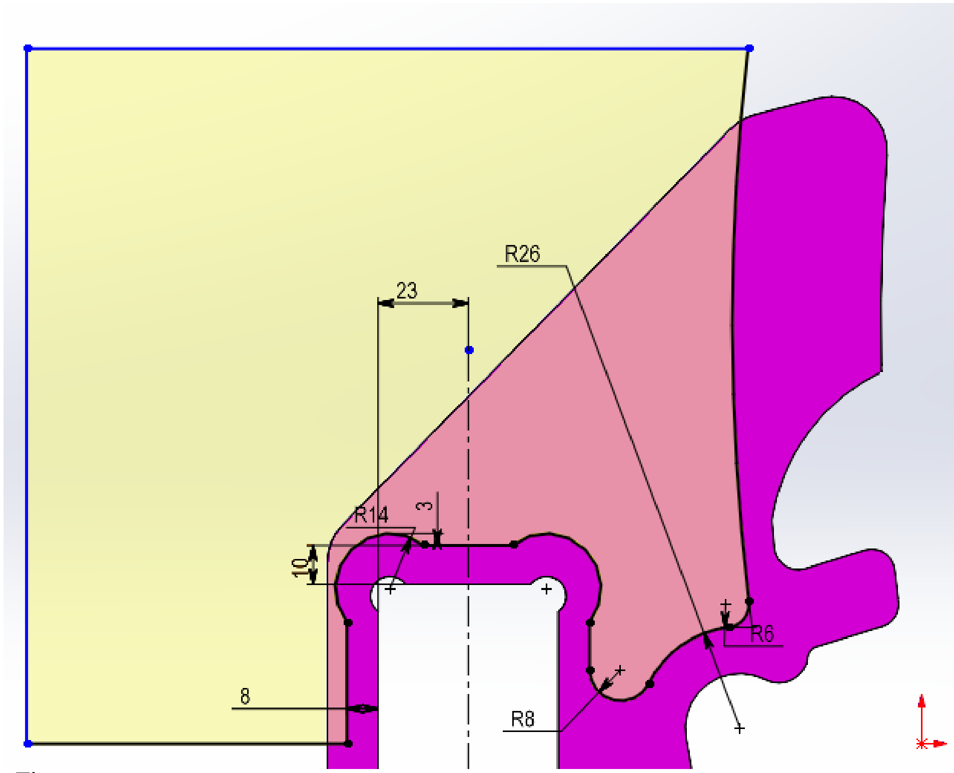

Figure 7.
Creating the profile for the cutout zone in the body of the non-rotating brake shoe.

b) Activate the "Linear Pattern" operation to create the lower part of the cutout zone; c) Perform the "Cut Extrude" procedure to the specified depth of the model (Figure 8a); d) Mirror the created zone of the model for the opposite part of the shoe (Figure 8b).

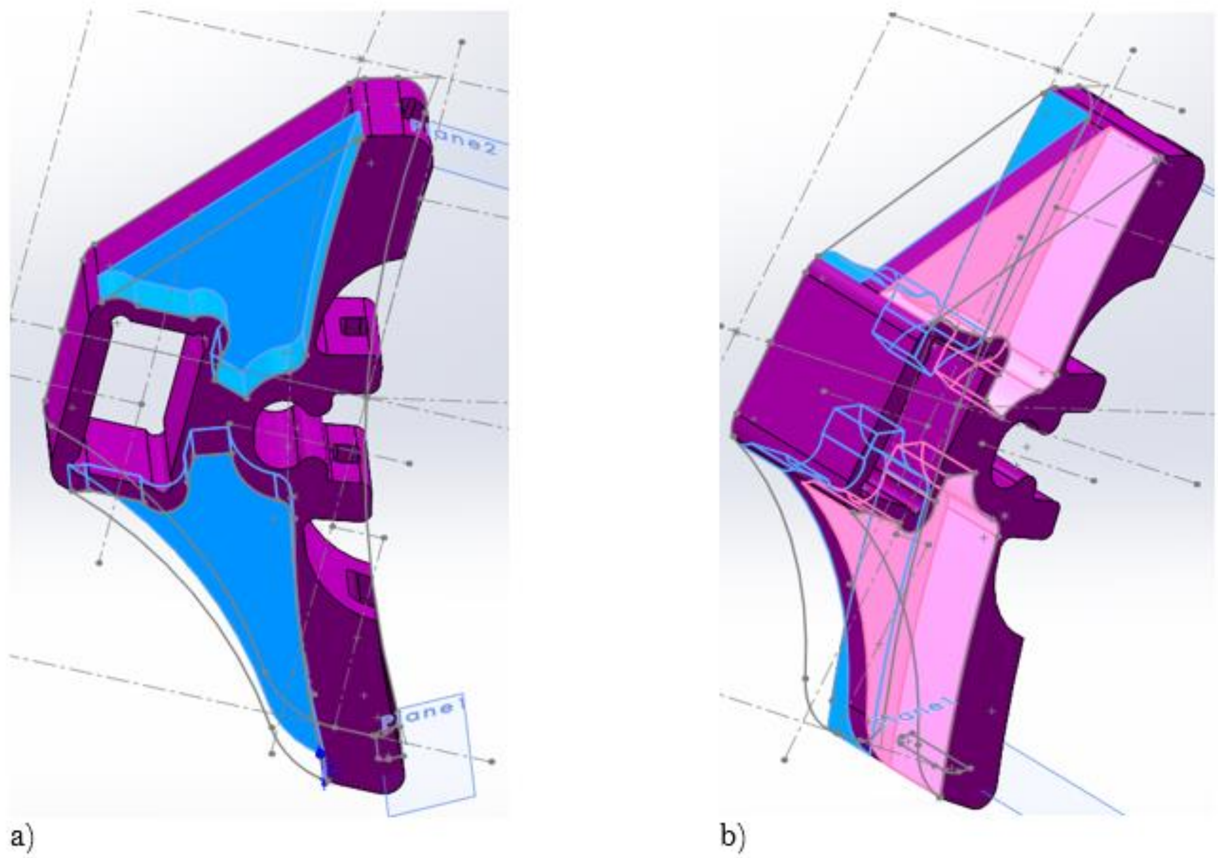

Figure 8.
Operations for creating cutout zones on the body of the non-rotating brake shoe model.

For ease of use of the brake shoe, we create fillets along the contour of the model and in the areas where it connects with the elements of the braking system. After performing all the listed operations, we obtain a model of the non-rotating brake shoe that can be used for the corresponding calculations (Figure 9).

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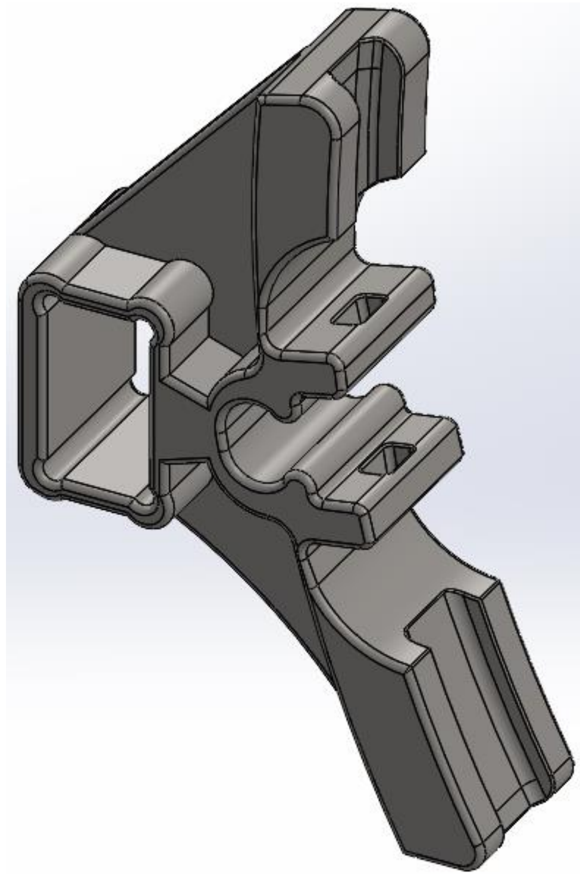

Figure 9.
Designed model of the non-rotating brake shoe.

After completing the design of the brake shoe, computer modeling is used to determine its strength. The finite element method, implemented in the SolidWorks Simulation software suite, is employed for this purpose. Strength analysis is conducted to establish the limit values of permissible stresses [59, 60]. This allows for the investigation of the mechanical properties of the functional 3D object, using the non-rotating brake shoe as an example, for future engineers and vocational education teachers (Feature Manager, Fig. 10a) [56, 61].

Thus, students will learn to perform strength calculations to select the optimal steel grade (Fig. 10b) that meets the strength requirements of the brake shoe [49, 62]. Additionally, during the strength calculation of the brake shoe in the SolidWorks Simulation software suite, students will be able to visually observe the stress distribution and focus on critical areas if they appear on the constructed profile. This will stimulate students' interest in quickly acquiring knowledge and enable them to better assimilate the educational material.

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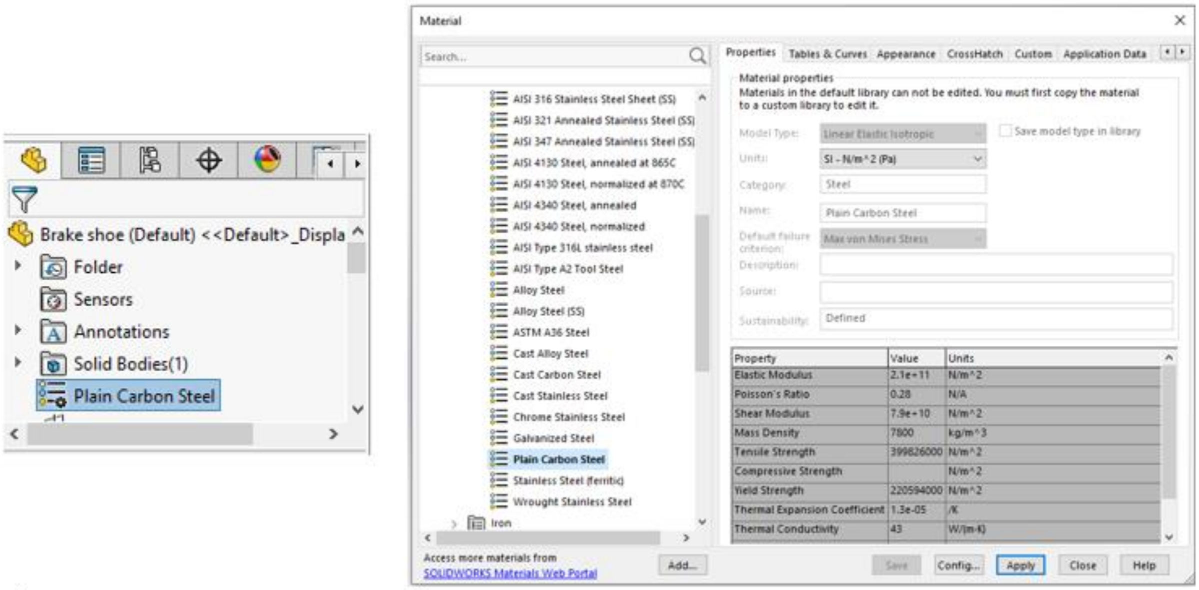

a) b)

Figure 10.
Material selection for the non-rotating brake shoe.

The implementation of a modern approach to computer modeling of functional 3D objects in the educational process for future engineers and vocational education teachers provides them with the necessary tools to solve complex problems, develop innovative thinking, and prepare for continuous self-improvement. These skills make them more competitive in the intellectual labor market, which demands not only deep knowledge in their field but also the ability to effectively apply this knowledge in various situations.

5. Results

The impact of the computer modeling project of a functional 3D object, exemplified by the non-rotating brake shoe, on learning outcomes was studied in a group of bachelor's students (12 students majoring in "Vocational Education (Mechanical Engineering)" at Yuriy Fedkovych Chernivtsi National University) during the course "Engineering Graphics and Machine Drawing". The assessment of students' learning outcomes was conducted through three tests administered "before" and "after" the implementation of the computer modeling project of the functional 3D object (Fig. 11). The maximum score for each test was 100 points. The test topics were related to modern approaches to computer modeling of functional 3D objects. The test questions covered theoretical knowledge and practical skills in the field of computer modeling of functional 3D objects.

Test No. 1 included questions on the topics of three-dimensional graphics and digital image processing. Test No. 2 focused on the use of the SolidWorks software suite for designing 3D objects. Test No. 3 included questions on the topic of investigating the mechanical properties of functional 3D objects using the SolidWorks software suite.

The analysis of the test results included calculating the mean score for each test for the group.

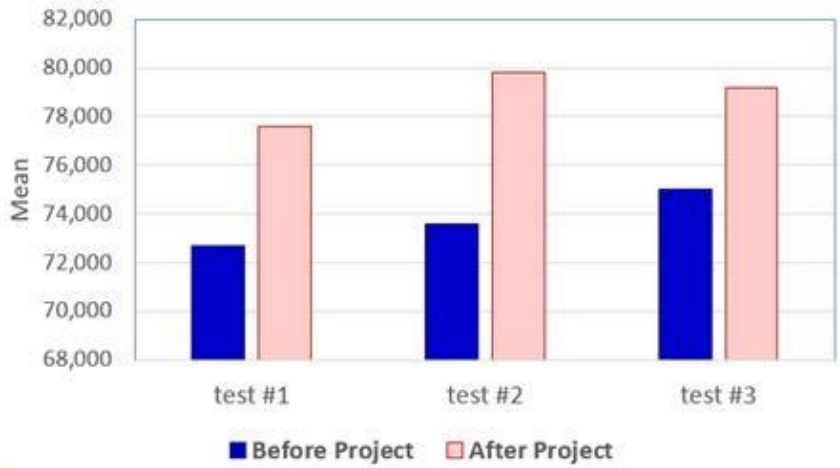

Figure 11.
Results of student testing “before” and “after” project implementation.

After the project implementation, the average test scores in the group increased by 5.1 points. The project is considered successful as there is an improvement in academic performance at all stages of the project.

6. Conclusion

The implementation of computer modeling of functional 3D objects in the educational process for future engineers and vocational education teachers is crucial for preparing qualified professionals capable of meeting the demands of the modern technological world. The use of the SolidWorks software suite has enabled students to acquire skills in three-dimensional modeling and apply mathematical concepts for in-depth analysis and understanding of functional objects, fostering the development of critical thinking and analytical abilities.

It has been established that tasks involving the analysis of graphical representations of functional 3D objects, such as non-rotating brake shoes for freight cars, allowed students to delve into the complexity of engineering solutions and produce high-quality, innovative solutions. This not only developed practical skills but also enabled students to better understand the application of mathematical models in real projects. Additionally, the properties and behavior of materials were studied through computer modeling, which is significant for preparing future engineers and vocational education teachers for real-world working conditions.

The features of the sketch creation and model construction process in the SolidWorks software suite have been formulated, with a primary focus on selecting the construction plane as the starting point of modeling. The process includes the use of geometric tools for approximate parameter settings with the possibility of subsequent adjustments, allowing for the achievement of the necessary accuracy and detail. It has been determined that different approaches to sketch construction can be optimized depending on the complexity of the model and the developer’s experience. This ensures effective design of functional 3D objects and enhances the educational process in higher education institutions, fostering the creative thinking of future engineers and vocational education teachers.

Thus, the integration of advanced technologies into the education of future engineers and teachers not only enriches their professional experience but also contributes to the formation of a strong professional identity, which is key to a successful career in today’s dynamic world. Such training enables graduates to stay ahead by offering innovative solutions and approaches in vocational education, which is essential for achieving high professional standards and effectively realizing educational potential.

References

[1] V. Kovalchuk, A. Androsenko, O. Derevyanchuk, N. Volkova, and Y. Piven, "Development of pedagogical skills of students of technology and pedagogical specialties using STEM technologies,"*Edelweiss Applied Science and Technology*," vol. 8, no. 4, pp. 498-506, 2024. https://doi.org/10.55214/25768484.v8i4.1125

[2] V. Kovalchuk, S. Maslich, N. Tkachenko, S. Shevchuk, and T. Shchypska, "Vocational Education in the Context of Modern Problems and Challenges," *Journal of Curriculum and Teaching*. vol. 11, no. 8, 2022. https://doi.org/10.5430/jct.v11n8p329

[3] Stratehiia rozvytku vyshchoi osvity v Ukraini na 2022-2032 roky [Strategy for the development of higher education in Ukraine for 2022-2032]. URL: https://www.kmu.gov.ua/npas/pro-shvalennya-strategiyi-rozvitku-vishchoyi-osviti-v-ukrayini-na-20222032-roki-286- [Accessed 25-08-2024].

[4] Future of Jobs Report 2023. World Economic Forum. May 2023. URL: https://www3.weforum.org/docs/WEF_Future_of_Jobs_2023.pdf [Accessed 25-08-2024].

[5] M. Pechuk, O. Soldea, E. Rivlin, "Learning function-based object classification from 3D imagery," *Computer Vision and Image Understanding*, vol. 110, no. 2, pp. 173-191, 2008. https://doi.org/10.1016/j.cviu.2007.06.002

[6] B. Kurent, and S. Avsec, "Interdisciplinary systems thinking and the ICT self-concept in higher education," *World transactions on engineering and technology education*, vol. 22, no. 2, pp. 70-76. 2024. URL: http://www.wiete.com.au/journals/WTE%26TE/Pages/Vol.%2022,%20No. 2%20(2024)/02-Avsec-S.pdf

[7] V. Kovalchuk, S. Maslich, N. Tkachenko, S. Shevchuk, and T. Shchypska, "Vocational Education in the Context of Modern Problems and Challenges," *Journal of Curriculum and Teaching*, vol. 11, no. 8, 2022. https://doi.org/10.5430/jct.v11n8p329

[8] Voitovych, I., Pavlova, N., Voitovych, O., Horbatiuk, R., Dubych (Muzychuk), K., Kovalchuk, V, and Prylepa, I., "Training of teachers STEM disciplines to work with students in distance education," *Inequality, Informational Warfare, Fakes and Self-Regulation in Education and Upbringing of Youth, Youth Voice Journal*, vol. I, pp. 103-112, 2023. URL: https://www.rj4allpublications.com/product/training-of-teachers-stem-disciplines/

[9] S. Balovsyak, O. Derevyanchuk, V. Kovalchuk, H. Kravchenko, Y. Ushenko, and Z. Hu, "STEM Project for Vehicle Image Segmentation Using Fuzzy Logic," *International Journal of Modern Education and Computer Science(IJMECS)*, vol. 16, no. 2, pp. 45-57, 2024. https://doi.org/10.5815/ijmecs.2024.02.04

[10] Kovalchuk, V., Vovk, L., Vovk, B., Stakhurska, I. and Leonova, A., "Developing the Creative Potential of the Future Vocational Training Teachers through the Prism of Cognition and Metacognition," *Youth Voice Journal*, vol. 14, no. 3, pp. 67-76, 2024.

[11] Iu. Lukianchuk, Yu. Tulashvili, V. Podolyak, R. Horbariuk, V. Kovalchuk, and S. Bazyl, "Didactic Principles of Education Students 3D-printing," *IJCSNS International Journal of Computer Science and Network Security*," vol. 22, no. 7 pp. 443-450. https://doi.org/10.22937/IJCSNS.2022.22.7.54

[12] O. V. Derevyanchuk, V. I. Kovalchuk, V. M. Kramar, H. O. Kravchenko, D. V. Kondryuk, A. V. Kovalchuk, and B. V. Onufriichuk, "Implementation of STEM education in the process of training of future specialists of engineering and pedagogical specialties," *Proceedings of SPIE*, vol. 12938, pp. 214-217, 2024. https://doi.org/10.1117/12.3012996

[13] Jóźwik Anna, and Cała Ireneusz, "An interdisciplinary approach to tall buildings teaching in architectural education," *World Transactions on Engineering and Technology Education, UNESCO - International Centre for Engineering Education*, vol. 22, no. 3, pp. 205-210, 2024.

[14] Nadi Suprapto, Iqbal A. Rizki, and Rahmatta T., "Lintangesukmanjaya and Imam Sya'roni. Wind, solar and water-powered renewable energy prototypes for STEM learning: testing their efficiency and feasibility," *World Transactions on Engineering and Technology Education*, vol. 22, no. 3, pp. 217-223, 2024.

[15] Y. Li, Y. Xiao, K. Wang, et al., "A systematic review of high impact empirical studies in STEM education," *International Journal of STEM Education(IJSTEM)*, vol. 9, no. 72, pp. 1-18, 2022. https://doi.org/10.1186/s40594-022-00389-1

[16] Y. Li, and Y. Xiao, "Authorship and topic trends in STEM education research," *International Journal of STEM Education(IJSTEM)*, vol. 9, no. 62, pp. 1-7, 2022. https://doi.org/10.1186/s40594-022-00378-4

[17] V. Kovalchuk, L. Shevchenko, T. Iermak, and K. Chekaniuk, "Computer modeling as a means of implementing project-based activities in STEM-education," *Open Journal of Social Sciences*, vol. 9, no. 10, pp. 173–183, 2021. https://doi.org/10.4236/jss.2021.910013.

[18] M. A. Samsudin, S. M. Jamali, A. N. Md Zain, and N. Ale Ebrahim, "The Effect of STEM Project Based Learning on Self-Efficacy among High-School Physics Students," *Journal of Turkish Science Education*, vol. 17, no. 1, pp. 94-108, 2020. https://doi.org/10.36681/tused.2020.15

[19] Juma'zoda Malika, and Farruh Ahmedov, "Effective Pedagogical Aspects of the Development of Creative Qualities in Students," *International Journal of Education and Management Engineering(IJEME)*, vol. 13, no. 1, pp. 35-40, 2023. https://doi.org/10.5815/ijeme.2023.01.05

[20] Sadi Mohammad, Ibrahim Adnan Chowdhury, Niloy Roy, Md. Nazim Hasan, and Dip Nandi, "Investigation of Student Dropout Problem by Using Data Mining Technique," *International Journal of Education and Management Engineering(IJEME)*, vol. 13, no. 5, pp. 43-61, 2023. https://doi.org/10.5815/ijeme.2023.05.04

[21] Dao Thi Thanh Loan, Nguyen Duy Tho, Nguyen Huu Nghia, Vu Dinh Chien, and Tran Anh Tuan, "Analyzing Students' Performance Using Fuzzy Logic and Hierarchical Linear Regression," *International Journal of Modern Education and Computer Science(IJMECS)*, vol.16, no. 1, pp. 1-10, 2024. https://doi.org/10.5815/ijmecs.2024.01.01

[22] Karanrat Thammarak, Witwisit Kesornsit, and Yaowarat Sirisathitkul, "Predictive Model for Academic Training Course Recommendations Based on Machine Learning Algorithms," *International Journal of Modern Education and Computer Science(IJMECS)*, vol.16, no. 3, pp. 17-26, 2024. https://doi.org/10.5815/ijmecs.2024.03.02

[23] Oleh Prokipchuk, Victoria Vysotska, Petro Pukach, Vasyl Lytvyn, Dmytro Uhryn, Yuriy Ushenko, and Zhengbing Hu, "Intelligent Analysis of Ukrainian-language Tweets for Public Opinion Research based on NLP Methods and Machine Learning Technology," *International Journal of Modern Education and Computer Science(IJMECS)*, vol. 15, no. 3, pp. 70-93, 2023.

[24] Serhiy Balovsyak, Oleksandr Derevyanchuk, Hanna Kravchenko, Yuriy Ushenko, and Zhengbing Hu, "Clustering Students According to their Academic Achievement Using Fuzzy Logic," *International Journal of Modern Education and Computer Science (IJMECS)*, vol. 15, no. 6, pp. 31-43, 2023. https://doi.org/10.5815/ijmecs.2023.06.03

[25] Vasyl Lytvyn, Olga Lozynska, Dmytro Uhryn, Myroslava Vovk, Yuriy Ushenko, and Zhengbing Hu, "Information Technologies for Decision Support in Industry-Specific Geographic Information Systems based on Swarm Intelligence," *International Journal of Modern Education and Computer Science(IJMECS)*, vol. 15, no. 2, pp. 62-72, 2023. https://doi.org/10.5815/ijmecs.2023.02.06

[26] Serhiy Balovsyak, Oleksandr Derevyanchuk, Vasyl Kovalchuk, Hanna Kravchenko, and Maryna Kozhokar, "Face Mask Recognition by the Viola-Jones Method Using Fuzzy Logic," *International Journal of Image, Graphics and Signal Processing(IJIGSP)*, vol. 16, no. 3, pp. 39-51, 2024. https://doi.org/10.5815/ijigsp.2024.03.04.

[27] Sun Fayou, Hea Choon Ngo, and Yong Wee Sek, "Combining Multi-Feature Regions for Fine-Grained Image Recognition," *International Journal of Image, Graphics and Signal Processing(IJIGSP)*, vol.14, no. 1, pp. 15-25, 2022. https://doi.org/10.5815/ijigsp.2022.01.02

[28] Vo Hoai Viet, and Huynh Nhat Duy, "Object Tracking: An Experimental and Comprehensive Study on Vehicle Object in Video," *International Journal of Image, Graphics and Signal Processing(IJIGSP)*, vol.14, no. 1, pp. 64-81, 2022. https://doi.org/10.5815/ijigsp.2022.01.06

[29] S. V. Balovsyak, and Kh. S. Odaiska, "Automatic Determination of the Gaussian Noise Level on Digital Images by High-Pass Filtering for Regions of Interest," *Cybernetics and Systems Analysis*, vol. 54, no. 4, pp. 662-670, 2018. https://doi.org/10.1007/s10559-018-0067-3.

[30] S. V. Balovsyak, O. V. Derevyanchuk, I. M. Fodchuk, O. P. Kroitor, Kh. S. Odaiska, O. O. Pshenychnyi, A. Kotyra, and A. Abisheva, "Adaptive oriented filtration of digital images in the spatial domain," *Proc. SPIE 11176, Photonics Applications in Astronomy, Communications, Industry, and High-Energy Physics Experiments*, vol. 11176, pp 111761A-1–111761A-6, 2019. https://doi.org/10.1117/12.2537165.

[31] S. V. Balovsyak, O. V. Derevyanchuk, and I. M. Fodchuk, "Method of calculation of averaged digital image profiles by envelopes as the conic sections," *Advances in Intelligent Systems and Computing*, Hu Z., Petoukhov S., Dychka I., He M. (Eds.), Springer International Publishing, vol. 754, pp. 204–212, 2019. https://10.1007/978-3-319-91008-6_21

[32] O. V. Derevyanchuk, H. O. Kravchenko, Y. V. Derevianchuk, and V. V. Tomash, "Recognition images of broken window glass," *Proceedings of SPIE*, vol. 12938, pp. 210-213, 2024. https://doi.org/10.1117/12.3012995.

[33] Ihor Tereikovskyi, Zhengbing Hu, Denys Chernyshev, Liudmyla Tereikovska, Oleksandr Korystin, and Oleh Tereikovskyi, "The Method of Semantic Image Segmentation Using Neural Networks," *International Journal of Image, Graphics and Signal Processing (IJIGSP)*, vol. 14, no. 6, pp. 1-14, 2022. https://doi.org/10.5815/ijigsp.2022.06.01.

[34] Kama Ramudu, Gajula Laxmi Bhavani, Manabolu Nishanth, Akula Prakash Raj, and Vamshika Analdas, "Level Set Segmentation of Images using Block Matching Local SVD Operator based Sparsity and TV Regularization," *International Journal of Image, Graphics and Signal Processing(IJIGSP)*, vol. 15, no. 2, pp. 47-58, 2023. https://doi.org/10.5815/ijigsp.2023.02.05

[35] S. V. Balovsyak, O. V. Derevyanchuk, H. O. Kravchenko, O. P. Kroitor, and V. V. Tomash, "Computer system for increasing the local contrast of railway transport images," *Proc. SPIE, Fifteenth International Conference on Correlation Optics*, vol. 12126, pp. 121261E1-7, 2021. https://doi.org/10.1117/12.2615761.

[36] V. M. Kramar, O. V. Pugantseva, and A. V. Derevyanchuk, "Spatial confinement, self-polarization and exciton-phonon interaction effect on the location of exciton line in lead iodide nanofilms," *Low Temperature Physics*, vol. 40, no. 8, pp. 766–770, 2014. https://doi.org/10.1063/1.4892649.

[37] Keerti Naregal, and Vijay Kalmani, "Exploratory Analysis of Access Control Mechanisms for Cloud-Based Iot," *International Journal of Education and Management Engineering (IJEME)*, vol.13, no. 3, pp. 39-46, 2023. https://doi.org/10.5815/ijeme.2023.03.05

[38] A. S. K. Wijayawardena, Ruvan Abeysekera, and M.W.P Maduranga, "A Systematic Review of 3D Metaphoric Information Visualization," *International Journal of Modern Education and Computer Science(IJMECS)*, vol. 15, no. 1, pp. 73-93, 2023. https://doi.org/10.5815/ijmecs.2023.01.06

[39] Nimesh Yadav, Aryan Sinha, "Augmented Reality and its Science", *International Journal of Education and Management Engineering(IJEME)*, vol. 12, no. 6, pp. 33-44, 2022. DOI:10.5815/ijeme.2022.06.04

[40] Martha Segura, Ramiro Osorio, Adriana Zavala, "Extended Reality Model for Accessibility in Learning for Deaf and Hearing Students (Programming Logic Case)", *International Journal of Modern Education and Computer Science(IJMECS)*, vol. 15, no. 4, pp. 1-17, 2023. DOI:10.5815/ijmecs.2023.04.01

[41] V. G. Ravlyuk, "Determining the technical condition of rolling stock bushings by means of vibration diagnostics," *Eastern European journal of advanced technologies*, vol. 2, no 7(74), pp. 11–15, 2015. https://doi.org/10.15587/1729-4061.2015.39036

[42] V. Ravluyk, I. Derevianchuk, I. Afanasenko, and N. Ravluyk, "Development of electronic diagnostic system for improving the diagnosis reliability of passenger car brakes," *Eastern-European Journal of Enterprise Technologies*, vol. 2, no. 9(80), pp. 35–41, 2016. https://doi.org/10.15587/1729-4061.2016.66007

[43] V. V. Bondarenko, D. I. Skurikhin, R. I. Vizniak, V. H. Ravlyuk, and V. I. Skurikhin, "Experimental study of the method and device for wheel-sets acoustic monitoring of railway cars in motion," *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, no. 4, pp. 30–36, 2019. https://doi.org/10.29202/nvngu/2019-4/7

[44] T. Q. K. Lam, "Initial factors impacting vertical displacement, stresses, and propagation of cracks in three-layered steel fiber concrete beams. *Edelweiss Applied Science and Technology*, vol. 8, no. 3, pp. 156-180, 2024.

[45] Semotiuk O. P. Modern dictionary of foreign words. 2008. 374 p.

[46] P. M. Pavlenko, S. F. Filonenko, O. M. Cherednikov, and V. V. Treitiak. Mathematical modeling of systems and processes. 2017. 392 p.

[47] S. H. Lytvynova, "System of computer modeling objects and processes and features of its use in the educational process of general secondary education," Information Technologies and Learning Tools, vol. 64, no. 2, pp. 48-65, 2018.

[48] S. Panchenko, A. Lovska, V. Ravlyuk, A. Babenko, O. Derevyanchuk, O. Zharov, and Y. Derevianchuk, "Detecting the influence of uneven loading of the brake shoe in a freight car bogie on its strength," *Eastern-European Journal of Enterprise Technologies*, vol. 5, no. 7(125), pp. 6-13. 2023 https://doi.org/10.15587/1729-4061.2023.287791

[49] DSTU 7522:2014 Bashmak halmivnyi nepovorotnyi dlia vantazhnykh vahoniv zaliznyts kolii 1520 mm. Tekhnichni umovy [Non-swiveling brake shoe for freight cars on 1520 mm gauge railways. Technical specifications]. https://online.budstandart.com/ua/catalog/doc-page?id_doc=91112

[50] Elyazov, V. Ravlyuk, A. Rybin, V. Hrebeniuk, "Determination of parameters of abnormal wear of brake pads of freight cars," *E3S Web of Conferences*, vol. 166, no. 07004. 2020. https://doi.org/10.1051/e3sconf/202016607004

[51] V. Ravlyuk, M. Ravliuk, V. Hrebeniuk, V. Bondarenko, "Process features and parametric assessment of the emergence of the excessive wear for the brake pads of freight car bogies," *IOP Conf. Series: Materials Science and Engineering*, vol. 708, no. 012025, 2019. https://doi.org/10.1088/1757-899X/708/1/012025

[52] ERRI B 169/RP 4. Standardization of coach wheelsets. Standardization of a block-braked solid wheel (rim diameter 920 mm) for coaches with a maximum speed of 160 km/h. Standard wheelsets for block brakes. 1993.

[53] ORE B 106/RP 12. Standardization of coaches, Standardization of a block-braked solid wheel (tread diameter 920 mm) for coaches with a top speed of 160 km/h. Basic calculations. Utrecht 1989.

[54] S. V. Panchenko, G. L. Vatulia, A. O. Lovska, V. G. Ravlyuk, "Determination of the thermal stress state for the composite brake pad of a wagon at operational loads," *IOP Conf. Series: Earth and Environmental Science*, vol. 1254, no. 012141, pp. 1-12, 2023. https://doi:10.1088/1755-1315/1254/1/012141

[55] S. Panchenko, J. Gerlici., G. Vatulia, A. Lovska, V. Ravlyuk, A. Rybin, "Method for determining the factor of dual wedge-shaped wear of composite brake pads for freight wagons," *Communications. Scientific Letters of the University of Zilina*, vol. 26, no. 1, pp. B31-B40, 2023. https://doi.org/10.26552/com.C.2024.006

[56] SolidWorks. http://www.solidworks.com/

[57] M. M. Koziar, Yu. V. Feshchuk, O. V. Parfeniuk. Kompiuterna hrafika: SolidWorks: navchalnyi posibnyk [Computer Graphics: SolidWorks: A Study Guide], 2018. 252 p.

[58] S. Panchenko, J. Gerlici, A. Lovska, V. Ravlyuk, J. Dižo, J. Harušinec, "Study on the Strength of the Brake Pad of a Freight Wagon under Uneven Loading in Operation," *Sensors*, vol. 24, no. 2: 463, 2024. https://doi.org/10.3390/s24020463

[59] S. Panchenko., J. Gerlici., G. Vatulia, A. Lovska, V. Ravlyuk, J. Harusinec, "Studying the load of composite brake pads under high-temperature impact from the rolling surface of wheels," *EUREKA: Physics and Engineering*, vol. 4, pp. 155-167, 2023. https://doi.org/10.21303/2461-4262.2023.002994

[60] L. V. Kamkina, A. A. Nadtochii, A. M. Hryshyn, Yu. D. Stohnii. Osnovy naukovykh doslidzhen: navchalnyi posibnyk [Fundamentals of scientific research: a study guide]. 2013. 89 p.

[61] R. C. Sharma, "Modeling and simulations of railway vehicle system," *International Journal of Mechanical Engineering and Robotics Research*, vol. 1, no. 1, pp. 55-66, 2014.

[62] S. Panchenko, G. Vatulia, J. Gerlici, A. Lovska, V. Ravlyuk, "Study of the Strength of the Upgraded Brake Leverage of a Wagon Bogie," In: Arsenyeva O., Romanova T., Sukhonos M., Biletskyi I., Tsegelnyk Y. (eds) Smart Technologies in Urban Engineering (STUE 2023). *Lecture Notes in Networks and Systems*, vol. 807, pp. 243-254, 2023. https://doi.org/10.1007/978-3-031-46874-2_22