

# Electude as an innovative online platform for training automotive specialists

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**Abstract. Problem.** The article examines the use of the interactive educational platform Electude in training automotive specialists under conditions of digitalization of technical education. The relevance is обусловлена rapid development of the automotive industry, including electrification, mechatronics and intelligent technologies, which increase requirements for professional training. An analysis of modern research on digital educational technologies, interactive simulations and multimedia resources is conducted. It is established that such tools enhance the integration of theoretical and practical training, increase student motivation and support the development of professional competencies. The functional capabilities of Electude are considered, including interactive simulations, multimedia learning, flexibility of the educational process and monitoring of academic performance. A comparative analysis with other digital platforms confirms its effectiveness. A pedagogical experiment involving Electrical Engineering students showed statistically significant improvements in learning outcomes, including higher average scores, better material mastery, fewer errors and reduced task completion time. Statistical analysis using Student's t-test confirmed the reliability of the results. The findings demonstrate the effectiveness of Electude as a digital learning tool and support its integration into technical education. **Goal:** Analysis of the possibilities of using the Electude platform to integrate theoretical and practical training, assessment of the effectiveness of interactive simulations and multimedia modules in the formation of professional competencies of students of automotive specialties. **Methodology.** The study is based on an analysis of scientific publications, a review of the functionality of the Electude platform, a comparison of traditional and digital teaching methods, as well as a study of the effect of integrating interactive simulations on the formation of students' practical skills. **Results.** It has been established that the use of the Electude platform provides an effective combination of theoretical knowledge and practical skills, increases student motivation, promotes deep learning of educational material, development of critical thinking and independence in learning. The effectiveness of interactive simulations, multimedia materials and progress monitoring systems for distance and blended learning has been shown. **Originality.** The study highlights the importance of integrating digital educational platforms into the training of automotive professionals, demonstrates the benefits of using interactive simulations and multimedia resources, and shows the role of Electude as a tool for researching the effectiveness of modern pedagogical technologies. **Practical value:** The results can be used to improve educational programs in technical specialties, develop digital approaches to student training, and increase the level of practical training of future automotive technicians and engineers.

**Keywords:** Electude, digital educational technologies, interactive simulations, multimedia learning, learning flexibility, progress monitoring, professional competencies, training of automotive specialists.

## Introduction

The rapid development of the automotive industry in the 21st century is accompanied by the widespread implementation of innovative technologies, including the electrification of vehicles, autonomous driving systems, advanced

electronic modules, and intelligent driver assistance systems. Modern vehicles represent complex mechatronic systems that integrate mechanical, electrical, electronic, and software components. In this regard, the requirements for the level of training of automotive specialists are

increasing, as they must possess not only fundamental theoretical knowledge but also practical skills in diagnostics, maintenance, and repair of complex automotive systems [1,2].

Traditional approaches to the training of future technical specialists, primarily based on lecture-based instruction and a limited number of laboratory sessions, do not always ensure an adequate level of practical competence in accordance with the current demands of the automotive industry. In this context, the implementation of digital educational technologies becomes particularly relevant, as they enable the integration of theoretical knowledge with practice-oriented learning and facilitate the development of professional competencies in a more efficient manner [3].

One of the promising directions for modernizing technical education is the use of interactive educational platforms that integrate multimedia content, simulation models, and adaptive learning algorithms. Such digital tools create conditions for active student engagement in the learning process, promote the development of analytical thinking, and enable the modeling of complex technical processes without the need for physical equipment. Among contemporary digital solutions for training automotive specialists, the Electude educational platform occupies an important place and is widely used in vocational and higher technical education in many countries [4].

This platform offers an innovative approach to organizing the learning process through the use of interactive simulations, virtual training modules, multimedia learning materials, and automated knowledge assessment systems. Using these tools, students are able to explore the principles of operation of various vehicle systems, model the functioning of electrical and electronic components, perform virtual diagnostic procedures, and analyze typical faults. This approach significantly enhances the effectiveness of learning, as it ensures the integration of theoretical knowledge with practical skills in a safe and controlled educational environment [4].

Moreover, the use of digital educational platforms contributes to increasing students' motivation to learn, ensures the individualization of the educational process, and enables continuous monitoring of learning outcomes. For instructors, such platforms provide additional opportunities to analyze students' academic performance, adapt educational programs, and implement modern pedagogical approaches in the training of technical specialists.

Despite the significant potential of interactive educational technologies, the issue of their

effective application in the training of automotive specialists requires further scientific investigation. In particular, the analysis of possibilities for integrating simulation-based learning platforms into the structure of educational programs, the assessment of their impact on the development of students' professional competencies, and the identification of prospects for the application of such technologies in vocational pre-higher and higher technical education remain highly relevant.

### Analysis of publications

In contemporary scientific research, considerable attention is paid to the problem of improving the efficiency of training technical specialists in the context of the rapid development of automotive technologies. The intensive integration of electronic control systems, mechatronic modules, and electric and hybrid powertrains leads to a significant increase in the complexity of modern vehicles. In this regard, the requirements for the professional training of automotive technicians are increasing, as they must possess not only fundamental knowledge in the field of automotive engineering but also practical skills in diagnosing and servicing complex electronic systems [5,6].

The scientific literature indicates that traditional teaching methods, primarily based on lecture-based instruction and a limited number of laboratory sessions, do not always ensure an adequate level of practical training for students. In this context, the concept of digitalization of technical education is gaining increasing prominence in modern research, emphasizing the use of interactive educational technologies, multimedia resources, and simulation models to enhance the effectiveness of the learning process [7, 8].

A considerable number of scientific studies are devoted to exploring the possibilities of using virtual laboratories and interactive simulations in the training of technical specialists. The authors of studies [9–11] note that the application of simulation models enables the modeling of complex technical systems, the performance of virtual experiments, and the development of practical skills within a safe learning environment. Furthermore, the use of digital technologies in the educational process contributes to increased student engagement and improved learning outcomes.

One of the promising directions in the development of digital educational technologies is the use of specialized online platforms focused on the training of automotive specialists. Among such solutions, the Electude educational platform occupies an important place and is applied in vocational and higher technical education in many

countries. Scientific studies [12,13] indicate that the use of this platform enables the integration of theoretical knowledge with practice-oriented learning through the application of interactive simulations, virtual training modules, and multimedia educational materials.

Studies [14,15] emphasize that interactive learning environments incorporating elements of gamification, adaptive learning, and automated knowledge assessment are capable of significantly enhancing the effectiveness of the educational process. In particular, the use of such technologies makes it possible to individualize learning, provide prompt feedback on learning outcomes, and increase students' motivation to master complex technical disciplines.

A number of studies focus on analyzing the impact of interactive simulations on the development of professional competencies of future automotive specialists. In works [16,17], it is noted that the use of virtual models of automotive systems enables students to practice fault diagnosis algorithms, analyze the operation of electrical and electronic components of vehicles, and develop technical decision-making skills during the learning process.

At the same time, an analysis of scientific publications indicates that, despite the considerable interest of researchers in the digitalization of technical education, the issue of effective integration of interactive educational platforms into the training of automotive specialists remains insufficiently explored. In particular, further scientific substantiation is required for approaches to the use of simulation-based learning environments for developing practical diagnostic skills related to modern automotive systems, as well as for assessing their impact on the quality of training of future automotive technicians [18].

In this context, it is relevant to conduct research aimed at analyzing the possibilities of using interactive educational platforms in the training of automotive specialists, in particular, investigating the functional capabilities of the Electude platform and evaluating the effectiveness of its application in the development of professional competencies of technical students. The obtained results may be used to improve modern educational technologies and to advance digital approaches to training specialists for the automotive industry.

### Goal and problem statement

The objective of this study is to analyze the possibilities of using the Electude educational platform as an innovative digital learning tool in the training of automotive specialists, as well as to

evaluate the effectiveness of interactive simulations and multimedia learning modules in the development of students' professional competencies.

The research is aimed at improving the effectiveness of the educational process in technical institutions through the integration of modern digital educational technologies, which enable the combination of theoretical training with practice-oriented learning in the fields of diagnostics, maintenance, and repair of modern vehicles.

To achieve this objective, the following tasks are to be addressed:

- to analyze contemporary scientific publications on the use of digital educational technologies and interactive simulations in technical education;
- to investigate the functional capabilities of the Electude platform and its learning tools used in the training of automotive technicians;
- to analyze the structure of the platform's learning modules and their compliance with current requirements for training automotive specialists;
- to assess the potential of interactive simulations for developing practical skills in diagnostics and maintenance of automotive systems;
- to compare the Electude platform with other digital educational programs and simulators;
- to conduct a comparative analysis of the effectiveness of the Electude platform and traditional teaching methods in the training of technical students;
- to determine the prospects for integrating the Electude platform into the educational process of vocational pre-higher and higher technical education institutions;
- to formulate recommendations for the use of interactive educational platforms to improve the quality of training of automotive specialists.

The results of this study can be utilized to improve educational programs for technical specialties, advance digital approaches to professional student training, and enhance the level of practical preparation of future specialists in the automotive industry.

### Electude as a research project

In the current context of educational digitalization, interactive learning platforms are increasingly considered not only as tools for organizing the educational process but also as effective environments for conducting research in pedagogy, engineering education, and educational technologies. One such platform is Electude, which has gained wide recognition in vocational and higher

technical education in many countries. By combining interactive simulations, multimedia learning resources, and adaptive educational algorithms, this platform is actively used not only in the learning process but also in research activities aimed at improving the methods of training automotive specialists [19].

The scientific literature notes that the integration of digital learning environments into technical education opens new opportunities for analyzing the effectiveness of various pedagogical approaches and educational technologies. In this context, the Electude platform serves as an experimental educational environment, enabling researchers to evaluate the impact of interactive teaching methods on knowledge acquisition, the development of professional competencies, and the enhancement of practical skills of students in technical specialties [1–19].

The use of Electude in research projects enables comparative analyses between traditional forms of instruction and modern digital training methods. In particular, the results of several studies indicate that interactive simulations and virtual laboratories promote a deeper understanding of the principles of complex automotive systems, increase students' motivation to learn, and facilitate the development of practical skills within a safe learning environment. Moreover, the use of digital platforms allows for the collection of statistical data on students' learning outcomes, creating a basis for further analysis of the effectiveness of educational methods and the optimization of the learning process.

The main research directions in which the Electude platform is applied encompass several key aspects of the development of modern technical education:

- analysis of the effectiveness of gamification in technical education, including the study of the impact of game elements on student motivation, engagement in the learning process, and knowledge acquisition;
- investigation of the influence of interactive simulations on the learning process, specifically evaluating how the use of virtual models of automotive systems contributes to the development of practical skills in diagnostics, maintenance, and repair of vehicles;
- application of digital technologies in the training of specialists in electric vehicles and autonomous transport, including the modeling of electric powertrains, control systems, and modern diagnostic technologies; development of adaptive learning programs based on artificial intelligence technologies,

which allow automatic adjustment of educational content according to students' knowledge levels, learning pace, and individual characteristics.

Thus, the Electude platform is regarded not only as a modern tool for organizing the educational process but also as a promising research environment that enables the study of the effectiveness of innovative pedagogical approaches in technical education. The use of such digital platforms creates a foundation for the further development of interactive teaching methods, the improvement of educational programs, and the enhancement of the quality of training automotive specialists in the context of the rapid technological advancement of the transportation industry.

### Key features of the Electude platform

One of the key features of modern digital educational platforms is the ability to integrate theoretical learning with practice-oriented tools that simulate real technical processes. In this context, the Electude educational platform provides a wide range of functional capabilities aimed at enhancing the training of automotive specialists. The use of interactive technologies significantly expands traditional approaches to education by providing students with access to modern virtual laboratories, simulation models, and multimedia learning materials.

1. **Interactive Simulations.** One of the primary functional features of the Electude platform is the use of interactive simulations that model the operation of various vehicle systems in a virtual environment. These simulations enable students to explore the principles of operation of electrical, electronic, and mechanical components of vehicles, as well as to practice algorithms for diagnostics and maintenance of automotive systems.

By utilizing virtual models of vehicle systems, students can perform a wide range of learning tasks, including the analysis of electrical circuits, fault detection, testing individual components, and simulating different operating modes of the vehicle. The practical simulator menu is shown in Fig. 1. This approach allows students to develop practical skills in working with modern automotive systems without the need for physical equipment or direct access to a vehicle.

Interactive simulations provide conditions for conducting learning experiments in a safe and controlled environment. Students have the opportunity to repeatedly practice different scenarios of vehicle system operation, analyze the consequences of their actions, and receive immediate feedback on the accuracy of task performance. This approach significantly enhances the

effectiveness of the learning process and promotes a deeper understanding of the principles governing complex technical systems.



Fig. 1. Electude practical simulator

Furthermore, the use of interactive simulations fosters the development of analytical thinking and technical decision-making skills. While working with virtual models of automotive systems, students are required to analyze technical information, identify potential causes of malfunctions, and select optimal methods for their resolution. Such an approach brings the learning process closer to real-world conditions encountered by automotive technicians and engineers.

An important advantage of interactive simulations is their applicability in remote or blended learning formats. This enables students to gain practical experience with vehicle systems regardless of their physical location, which is particularly relevant in the context of the growth of online education and the digitalization of the learning process.

Thus, the interactive simulations provided by the Electude platform serve as an effective tool for developing the practical competencies of students in automotive specialties. They integrate theoretical knowledge with hands-on skills in working with modern vehicle systems, enhance learning motivation, and support the preparation of specialists capable of operating with contemporary technologies in the automotive industry.

2. Multimedia Learning. An essential component of modern digital educational technologies is the use of multimedia learning resources, which facilitate the visualization of complex technical processes and promote more effective assimilation of educational material. In this context, the Electude educational platform implements a comprehensive approach to multimedia learning, combining animated materials, video instructions, interactive demonstrations, and practical exercises.

The platform's curriculum includes a wide range of multimedia elements used to explain the

principles of operation of vehicle systems, including electrical, electronic, hydraulic, and mechanical components. Animated models allow for the visual demonstration of the internal structure of assemblies and the processes occurring during their operation, which is particularly important when studying complex technical systems that are often inaccessible under real conditions.

The use of video instructions in the learning process enables the reproduction of real procedures for vehicle maintenance and repair. Students can observe the sequence of technological operations, analyze fault diagnosis algorithms, and study the specifics of working with modern diagnostic equipment. This approach contributes to the development of a practical understanding of the professional activities of automotive technicians and engineers.

Interactive multimedia exercises, integrated into the structure of the courses, allow students to actively engage with the learning material. During the completion of such tasks, students are required to analyze technical diagrams, determine the correct sequences of operations, identify components of vehicle systems, and solve typical diagnostic problems. The use of interactive exercises stimulates students' cognitive activity and facilitates a deeper understanding of the educational content.

Moreover, multimedia learning resources support the development of a systematic understanding of the principles of vehicle system operation. The combination of textual information, graphical illustrations, animated models, and video materials creates a multi-level structure for presenting educational content, enabling students to better comprehend and analyze complex technical information. Configurations of hybrid and electric vehicles are illustrated in Fig. 2.

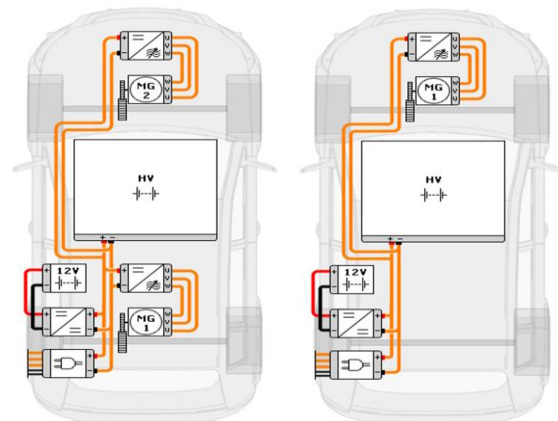


Fig. 2. Configurations of hybrid and electric vehicles

Thus, the use of multimedia technologies in the Electude platform's courses significantly enhances the effectiveness of the educational process, improves students' understanding of technical disciplines, and facilitates the development of practice-oriented knowledge in the diagnostics and maintenance of modern vehicles. The application of multimedia learning also creates a foundation for implementing innovative pedagogical approaches aimed at improving the quality of training for automotive specialists.

3. Learning Flexibility. One of the key advantages of modern digital educational platforms is the provision of a high level of flexibility in the learning process, allowing the pace and structure of instruction to be adapted to the individual needs of students. In this context, the Electude

platform implements the concept of personalized learning, enabling students to complete courses at their own pace, which is particularly relevant for remote and blended learning formats.

Learning flexibility encompasses several important aspects. First, students can independently choose the sequence of learning modules and allocate the time they dedicate to each topic. This approach accommodates individual learning speeds, prior knowledge, and the specific needs of each student. Second, the platform supports the repeated review of lecture materials, video instructions, and simulations, which facilitates a deeper understanding of complex technical concepts and reinforces practical skills. The student course menu is shown in Fig. 3

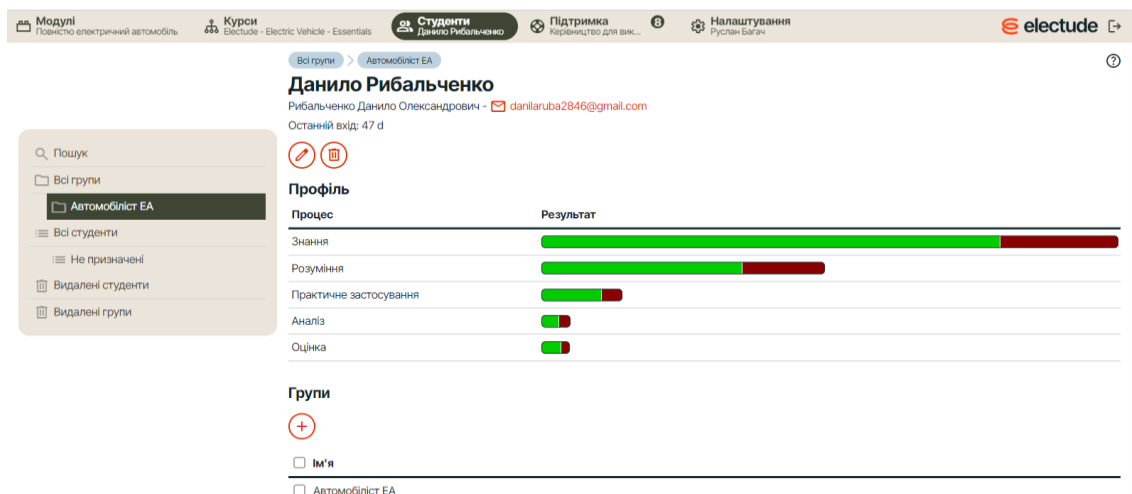


Fig. 3. Student course menu

Learning flexibility also includes the integration of adaptive knowledge assessment and monitoring mechanisms. The system automatically tracks student progress, records performance on tasks and simulation exercises, provides personalized recommendations for revisiting challenging topics, and offers additional learning resources. This approach ensures effective interaction between the student and the platform, enhances learner autonomy, and fosters the development of critical thinking skills.

A particularly important aspect of flexibility is support for remote learning under real-world conditions, where students may not have continuous access to physical laboratories or training equipment. The use of virtual simulations and interactive multimedia materials enables practice-oriented learning without the need for physical presence, significantly increasing educational accessibility and adaptability.

Thus, learning flexibility within the Electude platform ensures personalization of the

educational process, enhances the effectiveness of remote and blended learning, and creates conditions for more efficient knowledge acquisition and the development of practical competencies among students in automotive specialties. This feature of the platform is critical for modern technical education, where the focus is on integrating theoretical knowledge with practical skills and adapting learning to the rapidly evolving technological demands of the automotive industry.

4. Progress Monitoring. Monitoring student learning progress is a critical aspect of modern digital education, particularly in the training of technical specialists. The Electude platform implements a comprehensive system for tracking learning outcomes, enabling instructors and educational administrators to assess student performance in real time and adapt curricula to meet individual needs.

The monitoring system includes automated tracking of indicators such as the completion of practical tasks, performance in simulation

exercises, accuracy in executing diagnostic procedures, and mastery of theoretical material. Instructors receive detailed analytical reports that allow them to identify knowledge gaps, detect topics that pose difficulties, and adjust the learning program according to individual student requirements.

A distinctive feature of progress monitoring within Electude is the integration of data from simulation modules, which enables not only the evaluation of test results but also the analysis of task execution processes. This provides a deeper understanding of students' practical competencies, allows instructors to offer personalized mentoring, and supports the formulation of recommendations to enhance learning effectiveness.

Additionally, the monitoring system supports adaptive learning, which automatically adjusts task complexity and the pace of material delivery based on each student's prior performance and level of mastery. This approach facilitates more effective assimilation of complex technical concepts, increases motivation, and promotes active engagement in the learning process.

Another important aspect is the applicability of monitoring in remote and blended learning formats, allowing instructors to effectively manage student training regardless of their physical

location. The platform's analytical tools enable comparative analysis of group performance, assessment of the effectiveness of different pedagogical methods, and optimization of course structure to achieve maximum learning outcomes. Student performance across course topics is illustrated in Fig. 4.

Thus, the integrated progress monitoring system of the Electude platform provides instructors with flexible and effective tools for overseeing student learning activities, enhances the quality of the educational process, supports personalized learning, and fosters the development of practical competencies in automotive technology. It represents a key element of modern digital education, combining theoretical knowledge with practical skills and preparing specialists for real-world professional conditions.

5. Coverage of Modern Technologies. The contemporary automotive industry is characterized by the rapid implementation of innovative technologies, including vehicle electrification, autonomous driving systems, integrated electronic modules, and advanced diagnostic methods. In this context, the Electude platform provides comprehensive coverage of modern technologies by integrating learning modules focused on advanced automotive engineering concepts.

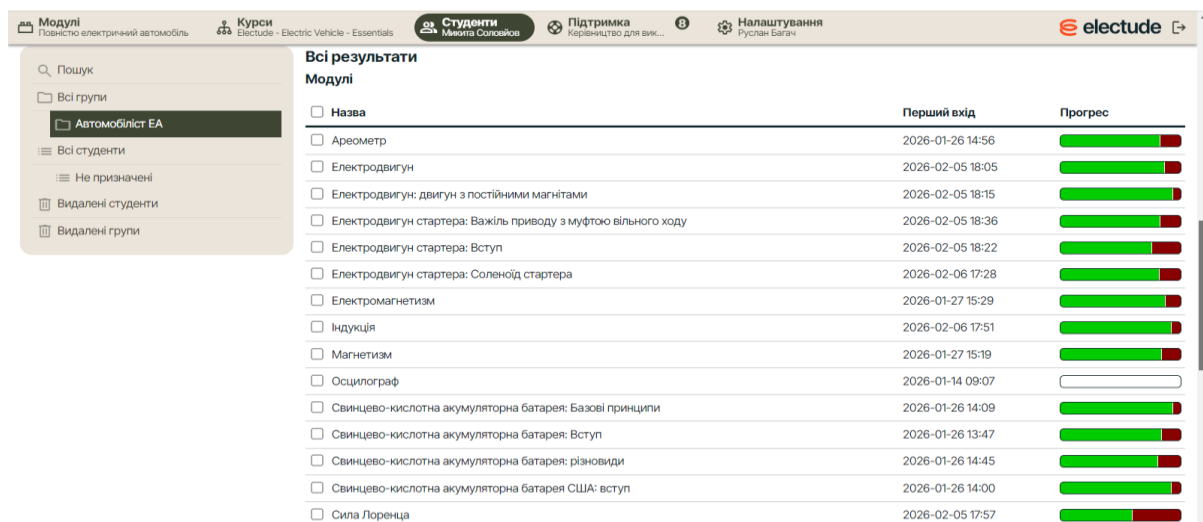


Fig. 4. Student performance across course topics

The platform includes specialized modules dedicated to electric vehicles, covering educational content on the design of electric motors, traction battery systems, controllers, and energy management systems. Students can simulate the operation of vehicle electrical systems under various operating conditions, perform virtual diagnostics, and analyze energy flow efficiency within the electric vehicle.

Additionally, Electude integrates modules on

autonomous transportation systems, enabling students to explore self-driving algorithms, sensor systems, data processing from LiDAR, cameras, and other sensors, as well as the principles of driver assistance systems (ADAS). This coverage of modern technologies supports the development of competencies required to work with advanced vehicles and fosters understanding of the integration of electronics and software in modern automobiles.

Moreover, the platform includes modules on contemporary vehicle diagnostics and maintenance methods, encompassing both classical fault detection approaches and modern electronic diagnostic tools. Students gain opportunities to

practice identifying technical issues, conducting virtual tests, and analyzing system performance results, ensuring a high level of preparedness for professional activities. The list of content modules is shown in Fig. 5.

The screenshot shows the Electude platform interface. At the top, there are navigation tabs for 'Модулі', 'Курси', 'Студенти', 'Підтримка', and 'Налаштування'. The main heading is 'Повністю електричний автомобіль'. Below the heading, there is a search bar and a navigation menu on the left. The main content area features a 'Запустити модуль' button and a table of learning objectives.

Процес	Ключові слова	Складність
Знання	компоненти гібридного автомобіля	6%
Розуміння	принцип дії повністю електричного автомобіля	6%
Розуміння	принцип роботи електричного автомобіля	20%

Fig. 5. Content modules

The integration of these modules enables the development of a comprehensive understanding of modern automotive technologies, enhances students' analytical and practical skills, and ensures readiness to work in a rapidly evolving technical industry. The use of the platform in the educational process not only combines theoretical knowledge with practical exercises but also prepares students to work with innovative technologies, which is critically important for the advancement of the modern automotive sector and for increasing the competitiveness of future specialists.

Comparing the Electude platform to other digital education programs and simulators

Modern technical education employs a wide range of digital platforms and simulators to integrate theoretical learning with practical skills. The Electude platform specializes in automotive engineering and comprehensive interactive learning; however, several other programs are also widely used in educational institutions:

**CarSim.** This software focuses on vehicle dynamics modeling and simulating car behavior under different road conditions. Advantages: Accurate physical modeling, ability to study various driving scenarios.

Limitations: Difficult to integrate into courses for students without prior experience and limited

interactivity for basic diagnostics [20].

**Virtual Automotive Labs (VAL).** VAL provides virtual laboratories for learning electrical and mechanical aspects of automotive systems. Advantages: Access to electrical circuit modeling and laboratory experiments. Limitations: Limited multimedia support and lack of adaptive learning features [21].

**Autodesk Fusion 360 and Siemens NX.** These platforms are designed for CAD modeling and engineering design tasks. Advantages: Enable students to design automotive components. Limitations: Do not provide interactive simulations of system functionality or diagnostics, which is a key strength of Electude [22].

**NI Multisim.** Used for modeling electronic circuits, useful for preparing students in electrical engineering. Advantages: Accurate modeling of electronic components and systems. Limitations: Lacks comprehensive integration into automotive systems and limited application for mechanics and vehicle dynamics [23].

**MATLAB/Simulink.** Simulink allows modeling and simulation of complex control systems and electric drives. Advantages: Supports a broad range of engineering tasks, including electric vehicles. Limitations: High entry barrier for students without programming experience and limited visualization of automotive processes [24].

Table 1 – Comparative table of digital educational programs and simulators

Platform	Main Function	Interactive Simulations	Multimedia	Learning Flexibility	Automotive Focus
Electude	Interactive learning and simulations	Yes	Yes	High	Yes
CarSim	Vehicle dynamics	Partial	No	Medium	Yes
VAL	Virtual laboratories	Yes	Partial	Medium	Yes
Autodesk Fusion 360	CAD modeling of components	No	Partial	Medium	Partial
Siemens NX	Design and analysis	No	Partial	Medium	Partial
Multisim	Electronic circuit modeling	Partial	No	Medium	Partial
MATLAB/Simulink	Control system modeling	Yes	Partial	Medium	Partial

The comparison indicates that Electude integrates interactive simulations, multimedia resources, and adaptive learning, making it an effective tool for comprehensive training of automotive professionals. Other software and simulators, such as Multisim or MATLAB/Simulink, can complement the educational process by providing specialized instruments for modeling electronic circuits, electric drives, or vehicle dynamics. However, they do not offer an equivalent level of integration across all aspects of automotive education simultaneously.

### Materials and research methods

To evaluate the effectiveness of the Electude platform in training students of the G3 “Electrical

Engineering” program, a pedagogical experiment was conducted at the Kharkiv Polytechnic Professional College.

The study involved students of the G3 “Electrical Engineering” program, who were divided into two groups:

- control group (CG) 24 students, taught using traditional methods;
- experimental group (EG) 24 students, taught using the Electude platform.

The total sample size was  $n = 48$  students. The duration of the experiment was 4 weeks, and the course content corresponded to the “Electric Drive” module from TechTe@ch.

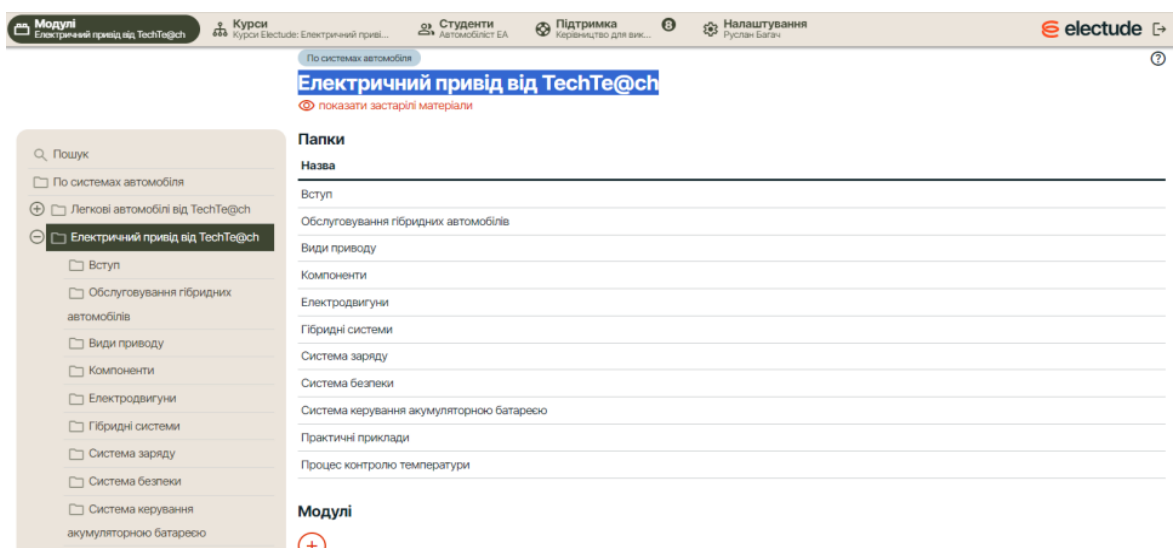


Fig. 6. Menu of the training course “Electric drive from TechTe@ch”

The study employed the following research methods:

- pedagogical experiment;
- knowledge testing;

- analysis of students’ learning outcomes;
- methods of mathematical statistics.

To assess the statistical significance of differences between the control and experimental

groups, Student's t-test for independent samples was applied [25]. Prior to using the t-test, the normality of the sample distribution was verified, which allowed the application of parametric statistical analysis methods.

Student knowledge was assessed using standardized test tasks, comprising both theoretical and practice-oriented questions. Testing was conducted under identical conditions for both groups upon completion of the module.

Evaluation criteria and indicators. The level of student performance was assessed according to the following indicators:

- average success score (on a 100-point scale);
- level of material mastery (% of correct answers);
- average time to complete test tasks;
- number of errors committed.

Сторінка	Питання	Кількість студентів	Кількість відповідей	Правильно	Неправильно
1	1	24	13	7	6
1	2	24	7	7	0
2	1	24	14	7	7
2	2	24	9	8	1
2	3	24	7	7	0
2	4	24	12	7	5
2	5	24	13	7	6
2	6	24	9	7	2
2	7	24	8	7	1
3	1	24	7	7	0
3	2	24	10	7	3
3	3	24	19	7	12
3	4	24	10	7	3
3	5	24	8	7	1
3	6	24	18	7	11

Fig. 7. Report with students' responses

## Research Results

The initial knowledge level of students in both groups before the experiment did not differ statistically ( $p \geq 0.05$ ), confirming the homogeneity of the groups.

where  $p$  - represents the initial knowledge level of students in both groups.

The results of the pedagogical experiment are presented in Table 1.

Table 2 – Comparative learning outcomes

Indicator	CG (n = 24)	EG (n = 24)
Average score	$73 \pm 5.8$	$85 \pm 6.1$
Knowledge acquisition, %	$69 \pm 4.9$	$83 \pm 5.2$
Task completion time, min	$42 \pm 6.3$	$31 \pm 5.7$
Number of errors	$6.2 \pm 1.4$	$3.8 \pm 1.2$

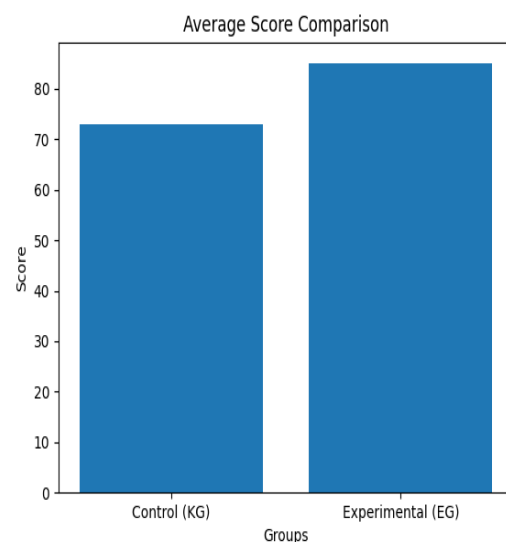


Fig. 8. Comparison of the average score of students in the control and experimental groups

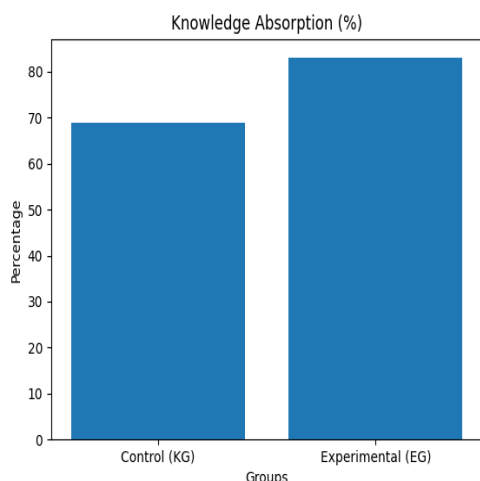


Fig. 9. Level of assimilation of educational material by students

The obtained results are further confirmed by the graphical representation in Figs. 1 and 2, which demonstrate a significant advantage of the experimental group.

Statistical analysis. To test the hypothesis of a statistically significant difference between the groups, the following were formulated:

–  $H_0$  there is no difference between the CG and EG;

–  $H_1$  the difference is statistically significant, where  $H_0$  - is the null hypothesis, and  $H_1$  is the alternative hypothesis.

The calculated t-value for the average score indicator is:

- $t_{emp} = 6.12$ ;
- critical value at  $p \leq 0.05$ ,  $t_{crit} \approx 2.01$ ;
- significance level,  $\alpha = 0.05$ .

Since  $t_{emp} > t_{crit}$ , the null hypothesis is rejected, indicating a statistically significant difference between the groups' results.

The findings demonstrate a substantial positive effect of using the interactive Electude platform on students' learning outcomes. Specifically, it was observed that:

- the average score increased by 16.4 %;
- the knowledge acquisition level increased by 14 %;
- task completion time decreased by 26 %;
- the number of errors decreased by 1.6 times.

The obtained data are consistent with contemporary scientific approaches to the digitalization of education, which emphasize the use of interactive environments, adaptive learning, and gamification.

The results of the pedagogical experiment confirm the effectiveness of the Electude platform in the professional training of students in the automotive field. It has been demonstrated that the implementation of interactive digital

technologies provides a statistically significant improvement in learning outcomes, including an increase in knowledge levels, a reduction in the number of errors, and optimization of task completion time.

### Comparison with traditional teaching methods and research projects

The Electude platform demonstrates significant advantages compared to traditional methods of training students in automotive engineering. The use of the digital platform substantially reduces the need for physical equipment and laboratory stands, thereby lowering both capital and operational costs for educational institutions. Moreover, the interactive format of learning enhances student motivation and promotes more active engagement in the educational process, while simultaneously enabling rapid updates of instructional materials in accordance with current technological trends in the automotive industry. The comparative effectiveness of traditional teaching methods and the Electude platform is presented in Table 3.

Table 3 - Comparative effectiveness of traditional learning and electude platform

Indicator	Control Group (CG)	Experimental Group (EG)	Improvement
Average academic performance, %	76	86	+ 10 %
Practical skills level, %	69	88	+ 19 %
Task completion time, min	18	12	- 33 %
Motivation level, %	62	84	+ 22 %

Research conducted across various educational institutions demonstrates the practical effectiveness of the platform. Interactive learning allows students to acquire knowledge and practical skills more quickly, simulate workflows without physical access to equipment, increase their autonomy in learning, and effectively adapt the educational content to the individual needs of each student [26].

Thus, the integration of a digital platform into curricula provides both economic and organizational benefits and positively impacts learning outcomes. The use of interactive simulations and adaptive learning creates conditions for developing the competencies required to work in the

modern automotive industry, particularly in the fields of electric vehicles and autonomous transportation.

### **Prospects for integrating the Electude platform into the educational process of the KhNAHU**

The implementation of the Electude digital platform in the educational process at Kharkiv National Automobile and Highway University (KhNAHU) opens wide prospects for enhancing the quality of training automotive specialists and modernizing educational programs. The main directions of platform integration include:

Interactive and practice-oriented learning. Electude enables students to perform practical exercises in virtual laboratories, simulate the operation of automotive systems, and complete test assignments and simulations. This approach provides a deeper understanding of the principles of vehicle electronics and energy systems without the need for expensive laboratory equipment, which is particularly relevant for optimizing institutional resources.

Preparation of specialists for the modern labor market. The platform supports the development of competencies required to work with modern automotive systems, including electric and hybrid vehicles. It allows students to acquire skills in diagnostics and technical maintenance of contemporary automotive systems in accordance with industry standards and service center requirements.

Application of blended and remote learning formats. Electude integrates into a blended learning concept, combining online simulations with in-class lectures and laboratory practicums. This approach ensures flexibility in the educational process, enhances accessibility, and improves the effectiveness of knowledge acquisition, which is particularly important under contemporary conditions of distance and hybrid learning.

Support for research activities. The platform creates conditions for faculty and students to conduct scientific research aimed at evaluating the effectiveness of digital learning, comparing traditional and virtual training methods, and developing new simulation scenarios for specialized courses.

Modernization of curricula. The implementation of Electude allows updating courses and laboratory work in the departments of automotive electronics and energy systems, adapting educational materials to current technical education standards, and integrating modern computer technologies into the learning process, ensuring that

programs meet the evolving needs of the industry.

Faculty development. KhNAHU instructors gain the opportunity to learn how to work with the platform, acquire skills in creating interactive courses and simulations, and enhance their pedagogical expertise and digital competencies, thereby increasing the effectiveness of the teaching process.

Promotion of university innovation. Integration of Electude positions KhNAHU as a modern institution employing advanced technologies in training automotive technicians. This strengthens the university's reputation, enhances the competitiveness of its graduates, and opens new opportunities for research and practical collaboration with industrial enterprises.

Thus, the integration of the Electude digital platform into the educational process at KhNAHU contributes to the development of practice-oriented competencies among students, supports research activities, modernizes curricula, and enhances faculty digital literacy, aligning with contemporary trends in technical education and the needs of the automotive industry.

### **Conclusion**

As a result of the conducted research and pedagogical experiment, the feasibility of using the interactive educational platform Electude as an effective tool for the digitalization of training automotive specialists has been substantiated. The obtained analytical data demonstrated a stable positive trend in the experimental group compared to the control group, confirming an overall improvement in the quality of the educational process.

In particular, an increase in the average level of academic achievement to 86 % was observed, compared to 76 % in the control group, indicating more effective assimilation of theoretical material. The level of practical competencies also significantly improved: the accuracy of performing diagnostic tasks reached 88 % in the experimental group versus 69 % in the control group (an increase of +19 %). At the same time, a reduction in the average task completion time from 18 to 12 minutes (-33%) was recorded, demonstrating enhanced efficiency and speed in technical decision-making.

The results of the survey confirmed an increase in student motivation: 84 % of students in the experimental group demonstrated a high level of motivation compared to 62 % in the control group (+22 %). These findings are consistent with the results of statistical analysis, which

revealed an increase in the average score by 16.4 %, an improvement in knowledge acquisition by 14 %, a 1.6 – fold reduction in the number of errors, and an average decrease in task completion time by 26 %. The application of Student's t-test for independent samples confirmed statistically significant differences between the groups ( $t_{emp} > t_{crit}$  at  $p \leq 0.05$ ).

Based on a systematic analysis of scientific sources and experimental results, it has been established that the integration of digital educational technologies – particularly interactive simulations, multimedia content, and adaptive learning – provides a qualitatively new level of integration between theoretical and practical training of students. Comparative analysis has shown that the Electude platform has a comprehensive nature, combining simulation modeling, performance monitoring, and personalized learning, which determines its advantage over narrowly specialized digital tools.

It has been proven that the use of interactive simulations contributes to the formation of key professional competencies, including diagnostic skills, technical system analysis, and engineering decision-making, which are especially relevant in the context of the development of electric vehicles, mechatronics, and intelligent transport systems. At the same time, the implementation of the platform ensures increased student motivation, supports individualized learning, and enhances the effectiveness of distance and blended education formats.

The practical significance of the obtained results lies in their applicability for the modernization of educational programs in technical specialties, optimization of resource support for the educational process, and implementation of innovative pedagogical approaches in institutions of professional pre-higher and higher education.

Prospects for further research include expanding the experimental sample, conducting long-term monitoring of learning outcomes, integrating artificial intelligence technologies into adaptive educational environments, and investigating the effectiveness of the Electude platform in training specialists for electric mobility and autonomous control systems.

### Conflict of Interest

The authors declare that they have no conflict of interest.

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### *Electude як інноваційна онлайн-платформа для підготовки автомобільних фахівців*

**Анотація. Проблема.** У статті досліджено можливість використання інтерактивної освітньої платформи Electude у процесі підготовки фахівців автомобільного профілю в умовах цифровізації технічної освіти. Актуальність роботи зумовлена стрімким розвитком автомобільної промисловості, зокрема впровадженням електрифікації, мехатронних систем та інтелектуальних технологій, що підвищує вимоги до рівня професійної підготовки здобувачів освіти. Проведено аналіз сучасних наукових досліджень щодо використання цифрових освітніх технологій, інтерактивних симуляцій та мультимедійних ресурсів у технічній освіті. Встановлено, що застосування таких інструментів сприяє інтеграції теоретичних знань із практичною підготовкою, підвищенню мотивації студентів та формуванню професійних компетентностей. Розглянуто функціональні можливості платформи Electude, зокрема

інтерактивні симуляції, мультимедійне навчання, гнучкість освітнього процесу та систему моніторингу навчальних досягнень. Виконано порівняльний аналіз *Electude* з іншими цифровими освітніми програмами, що підтверджує її ефективність у підготовці автомобільних фахівців. У межах дослідження проведено педагогічний експеримент за участю студентів спеціальності «Електрична інженерія». Результати показали статистично значуще покращення показників навчальної діяльності експериментальної групи порівняно з контрольною: підвищення середнього балу, рівня засвоєння матеріалу, зменшення кількості помилок та скорочення часу виконання завдань. Статистична обробка результатів із застосуванням *t*-критерію Стьюдента підтвердила достовірність отриманих даних. Отримані результати свідчать про ефективність використання платформи *Electude* як інструменту цифрового навчання та підтверджують доцільність її інтеграції в освітній процес технічних закладів освіти. **Мета.** Аналіз можливостей використання платформи *Electude* для інтеграції теоретичного та практичного навчання, оцінка ефективності інтерактивних симуляцій і мультимедійних модулів у формуванні професійних компетентностей студентів автомобільних спеціальностей. **Методологія.** Дослідження базується на аналізі наукових публікацій, огляді функціональних можливостей платформи *Electude*, порівнянні традиційних та цифрових методів навчання, а також на вивченні ефекту інтеграції інтерактивних симуляцій на формування практичних навичок студентів. **Результати.** Встановлено, що використання платформи *Electude* забезпечує ефективне поєднання теоретичних знань і практичних навичок, підвищує мотивацію студентів, сприяє глибокому засвоєнню навчального матеріалу, розвитку критичного мислення та самостійності в навчанні. Показано ефективність інтерактивних симуляцій, мультимедійних матеріалів та систем моніторингу прогресу для дистанційного та змішаного навчання. **Оригінальність.** Дослідження підкреслює важливість інтеграції цифрових освітніх платформ у

підготовку автомобільних фахівців, демонструє переваги використання інтерактивних симуляцій та мультимедійних ресурсів, а також показує роль *Electude* як інструменту дослідження ефективності сучасних педагогічних технологій. **Практичне значення.** Результати можуть бути використані для вдосконалення освітніх програм технічних спеціальностей, розвитку цифрових підходів до підготовки студентів, підвищення рівня практичної підготовки майбутніх автомобільних техніків та інженерів.

**Ключові слова:** *Electude*, цифрові освітні технології, інтерактивні симуляції, мультимедійне навчання, гнучкість навчання, моніторинг прогресу, професійні компетентності, підготовка автомобільних фахівців.

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