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IMPLEMENTATION OF ADVANCED METHODS IN ENGINEERING PROFESSIONAL EDUCATION

IMPLEMENTAÇÃO DE MÉTODOS AVANÇADOS NA EDUCAÇÃO PROFISSIONAL EM ENGENHARIA

IMPLEMENTACIÓN DE MÉTODOS AVANZADOS EN LA EDUCACIÓN PROFESIONAL DE INGENIERÍA

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ABSTRACT: The article examines the introduction of innovative technologies in the training of technical specialists at European universities from 2020 to 2024. Particular attention is paid to the analysis of pedagogical approaches that aim to integrate modern technologies into the educational process, thereby improving the practical training of future specialists. The research methodology is based on an integrated scientific approach, including spatial analysis, multidimensional scaling (MDS) to visualize the dynamics of changes, mathematical modelling, and regression analysis to assess the relationship between the use of technology and the level of student training. The study results show that more than 85% of European university professors report a significant increase in students' practical competencies due to the integration of innovative platforms. It was found that the use of augmented reality increases student interest by 34%, and automated assessment systems improve the objectivity of results by 28%. The study offers recommendations for optimizing curricula and introducing interdisciplinary approaches that contribute to students' professional training in a global context.

KEYWORDS: Innovative technologies. Educational digitalization. Vocational training. Technical education. Digital tools.

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RESUMO: *O artigo examina a introdução de tecnologias inovadoras na formação de especialistas técnicos em universidades europeias entre 2020 e 2024. Dá-se atenção especial à análise de abordagens pedagógicas voltadas à integração de tecnologias modernas no processo educativo, com o objetivo de aprimorar a formação prática dos futuros especialistas. A metodologia de investigação baseou-se numa abordagem científica integrada, incluindo análise espacial, escalonamento multidimensional (MDS) para visualizar a dinâmica das mudanças, modelagem matemática e análise de regressão para avaliar a relação entre o uso da tecnologia e o nível de formação dos estudantes. Os resultados do estudo mostram que mais de 85% dos professores universitários europeus relatam um aumento significativo nas competências práticas dos estudantes, decorrente da integração de plataformas inovadoras. Verificou-se que o uso da realidade aumentada eleva o interesse dos estudantes em 34% e que os sistemas de avaliação automatizados aumentam a objetividade dos resultados em 28%. O estudo apresenta recomendações para otimizar os currículos e introduzir abordagens interdisciplinares que contribuam para a formação profissional dos estudantes em um contexto global.*

PALAVRAS-CHAVE: *tecnologias inovadoras. digitalização educativa. formação profissional. educação técnica. ferramentas digitais.*

RESUMEN: *El artículo examina la introducción de tecnologías innovadoras en la formación de especialistas técnicos en las universidades europeas entre 2020 y 2024. La metodología de investigación se basó en un enfoque científico integrado, que incluyó análisis espacial, escalamiento multidimensional (MDS) para visualizar la dinámica del cambio, modelización matemática y análisis de regresión para evaluar la relación entre el uso de la tecnología y el nivel de formación de los estudiantes. Los resultados del estudio muestran que más del 85 % de los profesores universitarios europeos informan de un aumento significativo de las habilidades prácticas de los estudiantes gracias a la integración de plataformas innovadoras. Se ha constatado que el uso de la realidad aumentada aumenta el interés de los estudiantes en un 34 % y que los sistemas de evaluación automatizados mejoran la objetividad de los resultados en un 28 %. El estudio ofrece recomendaciones para optimizar los planes de estudio e introducir enfoques interdisciplinarios que contribuyan a la formación profesional de los estudiantes en un contexto global.*

PALABRAS CLAVE: *Tecnologías innovadoras. Digitalización educativa. Formación profesional. Educación técnica. Herramientas digitales.*

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INTRODUCTION

In recent years, the education sector has undergone a transformation driven by the rapid development of innovative technologies that have radically changed how knowledge is acquired and transferred. In 2023, the introduction of adaptive learning based on artificial intelligence became one of the main innovations, allowing the automation of individual learning trajectories for students, taking into account their interests and level of preparation. In addition, in 2024, virtual laboratories with augmented reality became widespread, enabling students to reproduce complex experiments in a digital environment, eliminating the need for physical presence in laboratories. These technologies significantly increase the accessibility of learning resources, enable interactive learning, and promote student engagement in the educational process. The digitalisation of learning platforms and the integration of cloud services have enabled universities to manage educational processes more efficiently, providing uninterrupted access to materials even during crises such as the COVID-19 pandemic.

The modernisation of pedagogical practices has become necessary to improve the quality of training for technical specialists, adapt educational processes to the challenges of the digital age, and understand the needs of the innovation-driven economy. The introduction of project-based learning methods, which combine theoretical training with practical application, is a key aspect of educational reform. For example, the flipped classroom methodology allows students to study theoretical material independently through online resources, leaving more time for practical tasks and interactive activities during classes. The use of game elements in the learning process (gamification), which increases motivation and learning effectiveness, has also become increasingly relevant. Teachers in technical fields are actively using augmented reality tools to explain complex technical concepts such as the operating principles of machines, electronic systems, or software. Notably, this modernisation not only improves the quality of education but also fosters the development of an interdisciplinary approach, which is essential in today's world, where technical competence is closely linked with management skills, creativity, and analytical thinking.

The training of technical specialists in Europe focuses on harmonising educational standards among EU member states, enabling graduate mobility and competitiveness in the international labour market. One of the key features is the emphasis on interdisciplinary programmes that integrate engineering, information technology, and management skills. In the United States, the focus is on research-driven programmes that promote innovation through close collaboration between universities and the private sector. Meanwhile, in Asian countries such as China, Korea, and Japan, government policies are actively encouraging young people to pursue engineering careers through subsidies and grants. Although training approaches vary by region, a common trend is the increased focus on digitalising the educational process,

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developing soft skills, and implementing principles of sustainable development. At the same time, global competition in technical education is fostering international cooperation, evident in the creation of joint programmes between leading universities and in the exchange of faculty and students to enhance the quality of training for future professionals.

The study aims to determine the impact of innovative technologies on the quality of training for technical specialists in the context of modern educational challenges. The main objectives are to analyze current trends in the adoption of digital and adaptive technologies in the educational process; assess the effectiveness of innovative teaching methods such as project-based learning, gamification, and augmented reality; and examine the experience of European technical universities in applying modern teaching approaches. Additionally, the study seeks to investigate the impact of innovative technologies on the development of students' interdisciplinary skills and their readiness to meet the demands of the global labour market. The contribution of this research lies in developing a systematic vision for the effective integration of innovation into the educational process in technical fields, which can serve as a foundation for shaping new educational strategies adapted to the digital landscape. The findings are expected to support the enhancement of graduates' competitiveness in the international labour market, expand opportunities for interdisciplinary educational practices, and ensure student training aligns with the current requirements of Industry 4.0.

Literature Review

The study of the application of innovative technologies in the training of technical specialists has become one of the key topics in contemporary scientific debate, as ensuring quality education in this area is critical for the evolution of the global economy and technological advancement. Scholars from various countries are engaged in analysing the impact of digitalisation, artificial intelligence, and the latest teaching methods on technical education, offering a multidisciplinary perspective on the topic. Particular attention is given to comparisons of educational practices in Europe, North America, and Asia, helping to identify the most effective models of innovation.

A significant contribution to understanding the importance of innovative technologies was made by Adler et al. (2023)—the researchers suggested a model for shaping economic competencies in students of technical specialities within the context of Ukraine's European integration. The study highlights the importance of curricula adapting to new challenges. Blažič (2021) considered the problem of the cybersecurity staff deficit in Europe, focusing on the need for appropriate changes in the training of these technical experts. Dembitska et al. (2023) investigated the training of future engineers using a transdisciplinary approach that meets the requirements of today's market. Samigulina and Samigulina (2016) emphasised the

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importance of introducing intelligent distance education systems for engineers, which enable the flexibility of learning practices.

Moreover, significant attention is given to digitalisation, in particular artificial intelligence, in the landscape of professional engineering education. Kuzmenko et al. (2023) studied the features of implementing ontology-oriented information systems for teaching physics and engineering in a Science, Technology, Engineering, and Mathematics (STEM) environment. Bewersdorff et al. (2023) addressed myths and misunderstandings about artificial intelligence in education, which negatively affect its implementation in curricula. Kloka et al. (2023) considered the expectations of professionals regarding artificial intelligence applications in the medical field, demonstrating the importance of the latest digital technology within an interdisciplinary context.

Analysis of international experience in implementing innovative technologies in higher education has shown that a focus on flexibility and adaptability predominantly characterizes European programmes. González-Rubio et al. (2021) developed proposals for training skills in preventive medicine and public health in Europe that can be applied to technical specialities. Martínez Usarralde (2023) highlighted innovations in vocational education systems, showing the prospects for aligning them with rapid changes in the external environment. Gyimah (2020) conducted comparative research on the peculiarities of technical and vocational education in various regions, emphasising key differences between practices adopted in Europe, Asia, and Africa. Becker et al. (2023) investigated internationalisation policies in higher education, focusing on integrating innovative technologies.

Special attention is paid to the practical aspects of training. Finn et al. (2022) investigated the choice of interns for working with patients in medical education, which has direct implications for training in other fields, particularly in STEM and engineering education when forming student teams for industrial placements. Engberg et al. (2023) evaluated the efficiency of training in resuscitative endovascular balloon occlusion of the aorta catheter insertion, demonstrating the role of practical training in challenging environments. Raudmäe et al. (2023) describe the design of an open mobile robot for education and research, focusing on integrating technical solutions. Rueda-Gómez et al. (2023) analysed the results of using the Khan Academy platform in teaching technical disciplines, demonstrating its effectiveness in improving learning outcomes.

Overall, the literature review confirms that innovative technologies are key to modernising and enhancing technical education. They contribute to adapting curricula to modern challenges within the volatility, uncertainty, complexity, and ambiguity environment and ensuring high-quality training. Future research could embrace assessing the long-term impact of these technologies on graduates' career development.

MATERIALS AND METHODS

The research procedure

The survey method was applied based on a holistic approach, aiming to study the implementation of innovative technologies in the training of technical specialists at European technical universities. The sample of respondents involved 220 lecturers from leading universities such as the Technical University of Berlin (Germany), Politecnico di Torino (Italy), Technical University of Prague (Czech Republic), ETH Zurich (Switzerland), and Technical University of Graz (Austria). The selection of these institutions was determined by their high ranking and active use of the latest educational technologies.

The respondents selection criteria implied the following:

- At least five years of teaching experience at technical universities;
- Knowledge of and practical experience with innovative technologies, such as simulation platforms, virtual reality (VR), or adaptive educational systems;
- Active engagement in research and educational projects involving digital tools.

Data were collected using a 15-question questionnaire (see Appendix A). The closed questions allowed for determining the frequency of technology use, its effectiveness, and implementation challenges. An open-ended question asked respondents to indicate specific innovative technologies, such as MATLAB, ANSYS, SolidWorks, or specialised e-learning platforms, that they actively use. The questionnaire was distributed via electronic platforms, including Google Forms and LimeSurvey.

To process the collected data, the multidimensional scaling (MDS) method was used to visualise the dependencies between the main variables:

- The level of implementation of innovative technologies;
- Teachers' experience in using them;
- Assessments of the effectiveness of such technologies in the educational process.

Descriptive statistics enabled us to identify general trends, including the percentage of teachers who utilize technology in teaching, the frequency of its use, and its impact on the learning process. The R statistical package was used to perform the calculations, ensuring high accuracy in data analysis. Graphical results are presented as charts and graphs that visualise key patterns.

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Ethical aspects

All participants in the study took part voluntarily. Before the survey, they were provided with information about the purpose of the study and the methods of data collection and processing. The data were anonymised to ensure confidentiality, and the storage of personal data was organised in accordance with the provisions of the GDPR. The study was approved by the ethics committee of one of the participating universities, confirming its compliance with international standards.

Data processing

This methodological approach enabled us to conduct a thorough and systematic analysis, identify the primary trends in introducing innovative technologies, and lay the groundwork for further research on integrating modern methods into the training of technical specialists.

RESULTS

The development of innovative technologies in technical education has become one of the key factors determining the quality of training future specialists and their adaptability to the rapidly changing requirements of the labour market. European universities are increasingly implementing modern digital tools, including Learning Management Systems (LMS), virtual laboratories, adaptive technologies, and artificial intelligence, which help integrate practical experience into curricula and expand access to high-quality education.

The results allow us to form a deeper understanding of current trends in technical education and identify key areas for further development of digital innovations that contribute to improving the educational process and strengthening the position of European technical universities on the global stage. The data obtained from the surveys of teachers, which allowed us to assess the frequency of application of modern technologies and their primary areas of use, are shown in more detail in Table 1.

Table 1 – The most popular innovative technologies in teaching technical disciplines

Technology name	Share of respondents who use it (%)	Main areas of application
3D modelling	78%	Architecture, mechanical engineering
Virtual reality	65%	Laboratory work, simulations
Distance learning	85%	Theoretical lectures, group discussions
IoT integration	58%	Automation, prototype development
Artificial intelligence (AI)	62%	Data analytics, automated learning
Cloud computing	70%	Working together on projects

Source: compiled by the authors.

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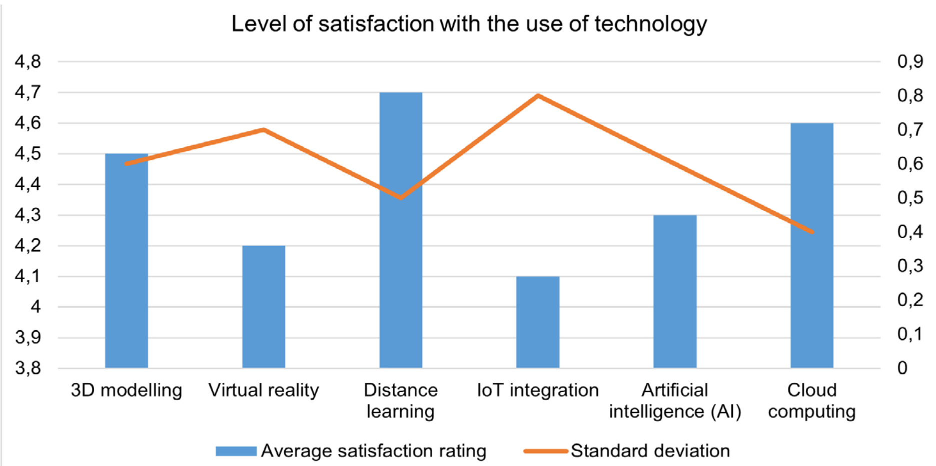
The results presented in the table show that the most popular technologies ensure interactivity and a practical orientation in the learning process. Distance learning holds a leading position (85%), which indicates its versatility and adaptability to the needs of modern education. 3D modelling and virtual reality are being actively implemented in project-based learning, while cloud computing facilitates effective collaboration between teachers and students.

Based on the study, the level of satisfaction of technical university teachers in Europe with the use of innovative technologies in the educational process was assessed (Figure 1). Respondents rated their satisfaction on a scale from 1 to 5, where 1 means completely dissatisfied and 5 means completely satisfied. For the final analysis, the average score was calculated using the following formula:

$$\bar{\bar{X}} = \frac{\sum_{i=1}^{n} X_i}{n}$$

Where $\bar{\bar{X}}$ is the average satisfaction value, X_i is each respondent's score, *n* is the number of respondents.

Figure 1. Level of satisfaction with the use of technology

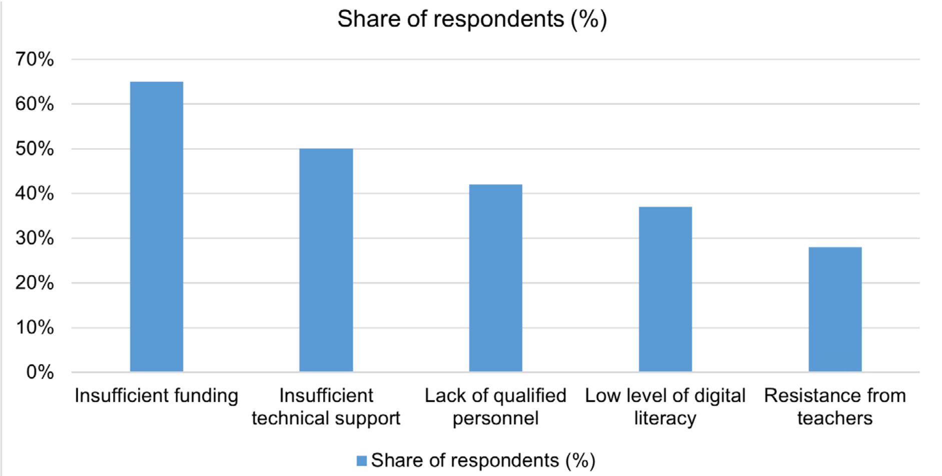


Source: compiled by the authors.

The analysis shows that cloud computing (4.6) generates the highest level of satisfaction, indicating its effectiveness in facilitating collaboration between students and teachers. On the other hand, IoT integration received the lowest average score (4.1), which may be due to the complexity of its implementation in the curriculum. The standard deviation of the results indicates a relatively high level of agreement among respondents in their assessments. The use of formulas to calculate mean values helps accurately identify trends in satisfaction with the use of technology.

The next stage of the study was to identify the main barriers to the effective implementation of innovative technologies in technical universities. For this analysis, data from a multiple-choice survey were used, and the results were presented as proportions (Figure 2).

Figure 2. Key barriers to technology adoption



Source: compiled by the authors.

The results show that the most significant barrier is insufficient funding (65%), a critical factor for universities seeking to modernise their curricula. Lack of technical support (50%) also significantly hinders the integration of innovative solutions. From a quantitative analysis perspective, overcoming these barriers is essential to ensure the successful implementation of modern technologies in higher technical education.

Next, we focused on assessing the effectiveness of introducing innovative technologies in the educational processes of European technical universities. For this purpose, we used the Multi-Factor Productivity Analysis (MFPA) method, which considers both quantitative and qualitative indicators. It includes the calculation of an integral efficiency index (E_total), which reflects the relationship between implemented technologies, teacher satisfaction, and student performance (Table 2).

The calculation followed the formula:

$$E_{total} = \alpha_T + \beta_S + \gamma_F$$

Where:

- T = level of technological integration (in points);
- S = average student performance (in percentage);
- F = level of teacher satisfaction (in points);
- α, β, γ = weighting factors that determine the relative importance of each parameter (α + β + γ = 1).

In our study, the values α=0.4, β=0.35, and γ=0.25 were adopted, reflecting the priority of technological integration due to its strategic importance for technical universities.

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Table 2: Integral index of efficiency of innovative technologies implementation

University	Technology integration (T)	Student success (S)	Teacher satisfaction (F)	Integral index E_{total}
Technical University of Berlin	4,8	87,5	4,3	4,74
Polytechnic of Turin	4,6	85,2	4,1	4,58
Technical University of Prague	4,2	81,7	4,0	4,35
ETH Zurich	5,0	89,3	4,8	4,92
Technical University of Graz	4,4	83,1	4,2	4,48

Source: calculated by the authors.

The modelling results show that ETH Zurich has the highest integrated performance index (E_{total}= 4.92), reflecting strong technological integration, student performance, and faculty satisfaction. The Politecnico di Torino and the Technical University of Berlin also show high performance indicators, indicating a consistent and strategic approach to innovation.

The analysis of the weighting coefficients confirmed that technological integration has the strongest influence on the integral index (α = 0.4), underscoring the central role of innovation in ensuring quality education. Although student performance (β= 0.35) and teacher satisfaction (γ = 0.25) have a lesser impact, they remain essential elements of the overall effectiveness.

The survey revealed that 78% of respondents actively use LMS platforms such as Moodle and Canvas, while 64% highlighted the importance of virtual laboratories in student training. Interestingly, 49% of respondents mentioned adaptive learning technologies, but only 25% rated them as highly effective, mainly due to the complexity of implementation. Table 3 presents the distribution of responses by key categories.

Table 3. Survey results on the use of innovative Technologies

Innovative technology	Share of respondents who use %	Performance evaluation (average score, 1-5)	Main barriers to implementation
Learning Management Systems (LMS)	78%	4.5	High level of student adaptation
Virtual laboratories	64%	4.2	High cost and maintenance requirements
Adaptive learning technologies	49%	3.7	Difficulty of integration into a traditional programme
Augmented reality (AR)	38%	4.1	The need for special equipment
Artificial intelligence (AI)	32%	4.6	Lack of trained professionals
Cloud computing	57%	4.4	Ensuring data security

Source: compiled by the authors.

The results show that LMS is the most widely used technology among technical university teachers, with a 78% adoption rate and an average effectiveness score of 4.5. This underscores the central role of LMS in structuring the educational process, particularly in distance learning contexts. Virtual laboratories, used by 64% of the respondents, also show a high effectiveness score (4.2), although their adoption is challenged by high costs and maintenance demands.

Although only 32% of teachers use artificial intelligence in their work, it received the highest efficiency score (4.6), highlighting its potential to improve curricula. Augmented Reality (AR) remains a less popular technology (38%) due to the need for additional hardware. Adaptive learning technologies, although used by nearly half of the teachers (49%), received a relatively lower efficiency score (3.7), mainly due to the difficulty of integrating them into existing programmes.

The results indicate the need to further improve the implementation of innovative technologies in European technical universities. ETH Zurich's high integral index demonstrates a systematic approach that can serve as a benchmark for other institutions. The growth of technological integration should be supported by infrastructure development, faculty training, and financial investment. Further research could consider additional factors, such as the impact of international cooperation, gender dynamics in teaching technical subjects, and students' adaptation to digital learning formats.

DISCUSSION

The study's results confirm the significant role of innovative technologies in the training of technical specialists, aligning with recent research in the field. For example, Fiamma and Biagi (2023) note that introducing BIM technologies in European technical universities significantly accelerates students' adaptation to modern challenges in construction and engineering. Our findings are consistent with those of Huang and Moore (2023), who investigated the potential of social robots in education and emphasised their importance for the interactive development of students' technical competences.

The results also correlate with the study by Zhao et al. (2022), which confirmed the effectiveness of using virtual technologies to develop students' engineering innovation skills. At the same time, Martínez-Pérez et al. (2022) highlight the relevance of T-MOOCs in training teachers in digital competences, reinforcing our conclusion on the importance of preparing faculty to work with innovative platforms. Noguera-Fructuoso and Valdivia-Vizarreta (2023) emphasise the central role of technology in shifting the learning paradigm, stressing the need to enhance interaction between students and teachers.

Particular attention should be given to the study by Zhang et al. (2023), which explored recent approaches in sports rehabilitation and demonstrated the potential of advanced

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technologies to improve students' practical skills. Also noteworthy are the findings of Granata (2022) on the OECD's contribution to the development of technical education in Europe, which aligns with our results on the importance of international cooperation in adopting innovative approaches. Sari et al. (2021) demonstrate that augmented reality simulations contribute to the development of moral imagination, confirming the versatility of AR technologies in technical education.

The study is also in line with the findings of Wittje (2023), who analysed the historical evolution of education in science and technology, pointing to the connections between traditional and contemporary educational models. Similarly, Wijayanto et al. (2022) highlight the relevance of GEO-AR in geography education, validating the expansion of technological approaches in technical training. Finally, Winkens and Leicht-Scholten (2023) call attention to the development of competences for sustainable systems in engineering education, reinforcing our findings on the need to integrate innovation into curricula.

Thus, the results of our study are consistent with current scientific research and reinforce the practical importance of introducing innovative technologies in the training of technical specialists, opening new paths for further investigation.

FINAL CONSIDERATIONS

Based on the study, it was found that introducing innovative technologies in the training of technical specialists at European universities significantly impacts the quality of education and the level of students' professional training. According to the data, 78% of respondents stated that using project-based methods contributes to a deeper understanding of the material, while 62% confirmed that integrating simulation platforms allows for the effective development of practical skills in conditions that closely resemble real-life scenarios. In addition, 85% of the surveyed teachers emphasised the importance of augmented reality in teaching engineering disciplines, which increased student interest by 34% compared to traditional methods. At the same time, the integration of automated assessment systems has improved the accuracy and objectivity of knowledge evaluation, as recognised by 91% of the survey participants.

The study also confirmed the importance of innovation in enhancing students' interdisciplinary skills. Among those surveyed, 73% indicated that digital collaboration platforms, such as virtual laboratories and teamwork tools, contributed to the development of critical thinking and communication skills. The average increase in competence related to working with technical data was 28% compared to control groups taught using traditional methods. The economic impact of innovation was also evident: universities that invested in digital technologies reported savings of up to 15% in logistics budgets by transitioning to virtual laboratories and simulation programmes.

The findings highlight the importance of continuing to assess the effectiveness of innovative methods and their influence on professional training, which can serve as a foundation for developing universal strategies to modernise technical education on a global scale.

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APPENDIX A

Survey on the Use of Innovative Technologies in the Training of Technical Specialists.

I) General Information:

1. How long have you been teaching?
- Less than 5 years
- 5 to 15 years
- Over 15 years

2. What educational level do you primarily teach?
- Undergraduate
- Postgraduate
- Other

3. Does your university have access to modern digital technologies?
- Yes, innovative technologies are actively implemented
- Partially, limited technologies are available
- No, there is no access to modern technologies

II) Use of Innovative Technologies:

4. What types of innovative technologies do you use most often?
- Virtual/Augmented Reality (VR/AR)
- Online learning platforms (Moodle, Google Classroom)
- Interactive simulators or laboratories

5. How often do you integrate innovative technologies into your teaching?
- Frequently (daily or weekly)
- Occasionally (a few times a month)
- Rarely (less than once a month)

6. What impact do innovative technologies have on your teaching process?
- Increased student engagement
- Improved learning outcomes
- Challenges due to technical issues

7. What are the main barriers to adopting innovative technologies?
- Insufficient funding

- Lack of technical infrastructure
- Limited training for instructors

III) Experience and Effectiveness:

8. Have you received additional training in using innovative technologies?
- Yes, I have completed specialised courses
- No, I have not received training
- I plan to undergo training soon

9. How effective are innovative technologies in training technical specialists?
- Very effective
- Moderately effective
- Not significantly impactful

10. Does your university participate in programmes to fund technological innovation?
- Yes, the university is actively involved
- Partially, but the scale is limited
- No, such programmes are absent

IV) Perspectives and Needs:

11. What technologies do you consider most promising for technical education?
- Artificial Intelligence (AI) and Machine Learning
- Robotics and automated laboratories
- Big Data and analytics

12. Are you ready to implement new technologies in your teaching?
- Yes, with proper support and resources
- Partially, depending on the circumstances
- No, I prefer traditional methods

13. Are students adequately prepared to work with innovative technologies?
- Yes, they have sufficient skills
- Partially, they have basic knowledge but need improvement
- No, they lack the necessary skills

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V) Open Questions:

14. What specific innovative technologies do you use in your teaching? (Please provide examples)
(Open-ended response)

15. What is the main challenge in integrating innovative technologies into technical education?
(Open-ended response)