

Yaropud, V. M. (2025). Implementation of innovations in technologies and engineering: European approaches and opportunities for Ukraine (Case of the Czech Republic). *Actual Issues of Modern Science. European Scientific e-Journal*, 38, 132–141. Ostrava.

DOI: 10.47451/tec2025-09-02

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Implementation of Innovations in Technologies and Engineering: European Approaches and Opportunities for Ukraine (Case of the Czech Republic)

Abstract: The article is devoted to the analysis of European approaches to implementing innovations in technologies and engineering, as well as to outlining the opportunities for their integration in Ukraine using the case of the Czech Republic. It is shown that modern engineering education and the agro-industrial sector are undergoing rapid transformations, where digitalization, environmental responsibility, and sustainable development become the key determinants of competitiveness. The European Green Deal and the Farm to Fork Strategy set clear requirements for energy efficiency, emission reduction, supply chain transparency, and the use of «smart» monitoring and management technologies. The study generalizes the Czech experience, where the combination of university training, short industrial R&D sprints, and joint laboratories with businesses ensures rapid knowledge transfer and high employability of graduates. The research methodology is based on comparative analysis of EU and Ukrainian policies and regulatory acts, the use of design thinking for structuring competencies, a logical-structural approach to shaping learning outcomes, and case analysis of university-business partnerships. The article proposes the architecture of an integrated dual model “university—R&D center—production” covering academic, research, and industrial blocks with clear quality indicators. An implementation roadmap (12–18 months) is presented, which includes resource auditing, redesign of educational programs aligned with EQF/NQF, establishment of joint laboratories, international partnerships, and integration of English-taught modules. It is demonstrated that Ukraine’s regulatory framework (EQF/NQF, licensing conditions, Laws «On Education» «On Higher Education» “On Innovation Activity” and the EU–Ukraine Association Agreement) provides the necessary foundation for scaling European practices. The conclusion emphasizes that the key success factors are the modernization of educational programs, continuous dialogue with business, internationalization, and the formation of a culture of measurable outcomes, which will enable the training of a «new wave» of engineers capable of addressing contemporary challenges.

Keywords: innovations, engineering education, European Green Deal, Farm to Fork Strategy, dual training, Czech Republic, digital engineering, R&D sprints, sustainable development, National Qualifications Framework.

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Впровадження інновацій у технологіях та інженерії: європейські підходи й можливості для України (кейс Чеської республіки)

Анотація: Стаття присвячена аналізу європейських підходів до впровадження інновацій у технологіях та інженерії та окресленню можливостей їх інтеграції в Україні на прикладі Чеської Республіки. Показано, що сучасна інженерна освіта й агропромислове виробництво перебувають у фазі швидких змін, де визначальними орієнтирами стають цифровізація, екологічна відповідальність і стійкий розвиток. Європейський зелений курс та стратегія «Від лану до столу» задають чіткі вимоги до енергоефективності, зниження викидів, прозорості ланцюгів постачання та застосування «розумних» технологій. У статті узагальнено досвід Чехії, де поєднання університетської підготовки, коротких індустріальних R&D-спринтів і спільних лабораторій з бізнесом забезпечує швидкий трансфер знань і високий рівень працевлаштування випускників. Методологія дослідження ґрунтується на порівняльному аналізі політик та нормативних актів ЄС і України, використанні дизайн-мислення для структурування компетентностей, логіко-структурного підходу до формування результатів навчання та кейс-аналізу партнерств університет–бізнес. Запропоновано архітектуру інтегрованої дуальної моделі «університет – R&D-центр – виробництво», що охоплює академічний, дослідницький і виробничий блоки з чіткими індикаторами якості. Представлено дорожню карту впровадження (12–18 місяців), яка передбачає аудит ресурсів, редизайн освітніх програм із прив'язкою до EQF/НРК, створення спільних лабораторій, міжнародні партнерства та інтеграцію англомовних модулів. Показано, що нормативна база України (EQF/НРК, ліцензійні умови, закони «Про освіту», «Про вищу освіту», «Про інноваційну діяльність», Угода про асоціацію з ЄС) створює необхідні умови для масштабування європейських практик. Зроблено висновок, що ключовими факторами успіху є оновлення освітніх програм, сталий діалог із бізнесом, інтернаціоналізація та формування культури вимірюваності результатів, що дозволить підготувати інженерів «нової хвилі» для сучасних викликів.

Ключові слова: інновації; інженерна освіта; Європейський зелений курс; стратегія «Від лану до столу»; дуальна підготовка; Чеська Республіка; цифровий інжиніринг; R&D-спринти; сталий розвиток; Національна рамка кваліфікацій.

Abbreviations:

EQF is European Qualifications Framework,

ESG is environmental, social, and governance,

LOs are learning outcomes,

NQF is National Qualifications Framework.

Introduction

Today, Ukrainian engineering education and the agro-industrial sector are undergoing a stage of rapid transformation. The key benchmarks are digitalisation, environmental responsibility, and sustainable development are factors that determine competitiveness in the modern world.

The European Green Deal (2019) and the Farm to Fork Strategy (2020) set a clear vector of development: the reduction of resource consumption and carbon emissions, transparency and controllability of supply chains, the advancement of organic production, and the application of “smart” monitoring and management technologies.

In the Ukrainian context, these priorities are aligned with the *Strategy for the Development of Agricultural, Food and Processing Industry Exports until 2026* (2019), which places a particular emphasis on the transition from a raw-material model to the production of high value-added goods.

Within such a political and institutional environment, there is an increasingly tangible demand for specialists capable of integrating innovative solutions into production processes. They must rely on European standards of quality, safety, and transparency, combining scientific approaches with practical management tools.

The purpose of the study is to generalise the approaches of the Czech Republic to the implementation of innovations in technology and engineering and to outline mechanisms for their incorporation into Ukrainian higher education institutions and enterprises.

To achieve this objective, the following tasks have been set:

- analyse the regulatory frameworks of the EU and Ukraine (the European Green Deal, the Farm to Fork Strategy, EQF/NQF, laws and resolutions of the Cabinet of Ministers of Ukraine);
- identify Czech educational models that ensure practice-oriented training and the rapid transfer of technologies;
- propose an architecture of integrated dual training “university—R&D centre—production”;
- present a roadmap for implementation, considering Ukrainian conditions.

Methods

Several complementary approaches were employed in this study. Firstly, a comparative analysis was conducted of key policies and regulatory documents: the European Green Deal (2019), the “Farm to Fork” strategy (2020), the Association Agreement between Ukraine and the EU (2014), as well as the Laws of Ukraine “On Education” (2017), “On Higher Education” (2014), “On Innovation Activity” (2002), and the resolutions of the Cabinet of Ministers concerning the National Qualifications Framework and licensing conditions (2011).

Secondly, design thinking tools were applied to structure competences and learning modules. Thirdly, a logical-structural approach was utilised to develop educational outcomes (Learning Outcomes) with reference to the EQF/NQF levels.

In addition, a case analysis of university-business partnerships in the Czech Republic and Ukraine performed out, which made it possible to assess effective practices of integrating innovation into the educational process.

Literature Review

The formation of an innovative model of engineering education in Europe is inseparable from the global sustainable development agenda and the digital transformation of production. The European Green Deal (2019) and the Farm to Fork Strategy (2020) have become strategic milestones for reconfiguring educational and industrial systems toward climate neutrality, responsible resource management, and circular economy models. These documents defined innovation not merely as technological modernisation but as an institutional mechanism for implementing the principles of ESG responsibility. According to the European Commission,

sustainability has become a cross-cutting criterion in funding educational and research programmes, including Horizon Europe and Erasmus+, and in shaping the competencies outlined by the EQF (*The European Green Deal, 2019; Farm to Fork Strategy, 2020*).

The EQF and the NQF of Ukraine (*On Approval..., 2011*) act as pivotal regulatory tools aligning educational outcomes with European standards. Their application ensures transparency, mobility, and mutual recognition of qualifications across borders (*On the European Qualifications Framework, 2017*). The NQF, approved by the Cabinet of Ministers of Ukraine, integrates the descriptors of professional competence and measurable learning outcomes, thereby enabling the harmonisation of engineering education with European benchmarks (*On Approval..., 2011*). This alignment fosters the comparability of Ukrainian degrees and their “readability” for European employers, a precondition for integrating national universities into international research and innovation networks.

A critical component of European innovation policy is the integration of education, research, and production, particularly within engineering disciplines. The Czech Republic demonstrates a successful dual-education model that combines academic instruction with practical industrial training. The implementation of this model is supported by the Association Agreement between Ukraine and the European Union (*2014*), which provides legal and financial instruments for joint projects in science, technology, and higher education. In this context, the Czech approach is noteworthy for its emphasis on short industrial R&D sprints, joint laboratories with enterprises, and a competency-based curriculum linked to real-world challenges. Such collaboration between universities and businesses ensures that graduates acquire both theoretical knowledge and applied technical skills, improving their employability and fostering innovation (*Association Agreement..., 2014*).

The Farm to Fork Strategy (*2020*) positions engineering education as a driver of ecological transformation in the agro-industrial sector, highlighting the need for technologies that support energy efficiency, emission reduction, and digital traceability of production processes. The integration of these principles into engineering curricula requires a redesign of educational programmes, embedding transversal competencies in sustainability, digitalisation, and entrepreneurship. Similar priorities are reflected in Ukraine’s Strategy for the Development of Agricultural, Food and Processing Industry Exports until 2026 (*2019*), which calls for a transition from raw-material exports to high value-added production through technological innovation and workforce development (*Strategy for the Development..., 2019*). Consequently, the modern engineer must possess a hybrid set of skills encompassing digital literacy, environmental awareness, and innovation management.

At the institutional level, the European Digital Europe Programme (2021–2027) further supports this transformation by funding initiatives in artificial intelligence, data spaces, high-performance computing, and advanced digital skills. These technologies underpin new methodologies of engineering education, including the use of digital twins, PLC/SCADA systems, IoT/IIoT networks, and machine learning for process optimisation. As a result, the engineer’s professional role evolves from that of an operator to that of a designer and integrator of complex technological systems (*A Digital Europe Programme, 2021*).

Legislative frameworks in Ukraine provide the necessary foundation for incorporating these European approaches. The Laws “On Education” (*2017*), “On Higher Education” (*2014*), and

“On Innovation Activity” (2002) outline mechanisms for academic autonomy, the integration of research into the educational process, and the commercialisation of intellectual property. These acts correspond with the EU’s vision of innovation ecosystems, where education serves as both the generator of knowledge and the incubator of entrepreneurial initiatives (*On Education, 2017; On Higher Education, 2014; On Innovation Activity, 2002*). The Law “On Licensing Conditions for Educational Activities” (2015) ensures quality assurance through strict requirements for facilities, staffing, and practical components, aligning national institutions with European accreditation practices (*On Licensing Conditions..., 2015*).

Results

The *Farm to Fork Strategy* (2020) establishes a new logic for the development of food systems: human health, environmental sustainability, and market competitiveness must be regarded as an integrated whole.

For engineers, this implies an entirely new set of technical requirements:

- energy efficiency of all processes;
- minimisation of losses and harmful emissions;
- digital tracking and data-driven management;
- the use of sensors, drones, and satellite monitoring;
- the implementation of digital twins, PLC/SCADA systems, and machine learning methods (*The European Green Deal, 2019; On Licensing Conditions..., 2015*).

In addition, the European Qualifications Framework (EQF) defines generalised levels of competences, while the National Qualifications Framework (NQF) of Ukraine renders these results ‘legible’ also to European employers (*A Digital Europe Programme, 2021; On the European Qualifications..., 2017*).

Accordingly, educational and professional programmes in engineering disciplines require redesign. They must integrate, in a transversal manner, competences in sustainable engineering, digital engineering, safety, product lifecycle management, and innovation entrepreneurship. This will enable the training of specialists capable of responding to the new challenges of the global market.

Czech technical universities demonstrate flexible models of combining education, R&D, and production:

- a) short industrial sprints within semester courses;
- b) joint laboratories with access to measurement and testing equipment;
- c) project modules commissioned by companies with clearly defined KPIs;
- d) mentoring by practising engineers in disciplines and interdisciplinary studies (data science for agriculture, mechatronics, eco-modelling).

The result is a rapid renewal of content, the conversion of student projects into prototypes and start-ups, co-authorship in publications and patents, and high levels of graduate employability.

The national regulatory framework provides a sufficient basis for scaling up European approaches. The Resolution of the Cabinet of Ministers of Ukraine approving the NQF establishes levels and enables alignment of LOs with the EQF; the Licensing Conditions for the

Provision of Educational Activity regulate resources, practices, and staffing; the Laws of Ukraine *On Education* and *On Higher Education* ensure institutional autonomy, the integration of education and research, and academic mobility; the Law *On Innovation Activity* provides tools for R&D collaboration, technology transfer, and IP management. The Association Agreement (articles on science, innovation, and education) opens channels for participation in European programmes and joint projects. Taken together, these form the legal basis for integrated dual trajectories and international placements.

The architecture of integrated dual training “university—R&D centre—production” is based on a three-phase model:

1. Academic block is modules in digital engineering (CAE/CFD, CAD/CAM/PLM), IoT/IIoT and cyber-physical systems, risk management, and LCA assessment;
2. Research block is engineering sprints, testing, prototyping, experimental design, scientific publications, and IP applications;
3. Production block is field cases in precision agriculture, implementation of automated solutions, energy efficiency audits, and post-project support.

Each block is linked to quality indicators: competence levels (EQF/NQF), employer-validated LOs, a set of artefacts (prototypes, patents, LCA reports, publications), and the share of implemented cases among partners.

The roadmap for implementation (12–18 months) includes:

- Stage 1, audit of programmes and resources: verification of compliance with Licensing Conditions, identification of gaps in laboratory infrastructure, and selection of industrial mentors.
- Stage 2, redesign of programmes: construction of a “competences–modules–LOs” matrix aligned with EQF/NQF; integration of micro-qualifications (simulations, GIS/drones, PLC/SCADA).
- Stage 3, launch of joint laboratories and R&D sprints; agreements on confidentiality and IP, testing schedules, and external evaluation mechanisms.
- Stage 4, scaling and internationalisation: double modules with Czech universities, reciprocal recognition of credits, participation in Horizon Europe consortia, implementation of English-taught tracks, and joint publications.

Educational tools and examples of modules:

- *Farm-to-Fork Engineering* is assessment of the resource footprint (water, soil, energy) of technological solutions, organic practices, and supply chain traceability.
- *Digital Ag Systems* are sensor networks, telemetry, satellite data, analytics, and visualisation.
- *Mechatronics for Agro* is robotic manipulators, drive systems, control and safety.
- *Sustainable Processing* is energy-efficient drying, heat and mass transfer, recuperation, and closed water cycles.
- *Data-Driven Maintenance* is predictive diagnostics, digital twins, vibration and load analysis.

At the level of higher education institutions: improved quality of engineering training, international transparency of qualifications, a higher proportion of students engaged in R&D and start-ups, and expanded partnerships and mobility. At the level of enterprises: reduced energy consumption and downtime, greater repeatability of quality, improved environmental

performance of products, and enhanced transparency and traceability. At the level of the economy: a shift to higher added-value products, strengthened positions in EU markets, and compliance with ESG requirements without loss of productivity.

Within university–industry partnerships, a joint precision agriculture laboratory is established with GIS/drone modules, machine telemetry, agrochemical sensors, and training plots. Students undertake engineering tasks: simulated and real task maps for input application, equipment control algorithms, scenarios for fuel and pesticide savings, and LCA evaluation of technological maps. The results are implemented with partners and serve as the basis for joint publications, patent applications, and commercialisation.

Normative and policy benchmarks:

- the European Green Deal; the EU *Farm to Fork Strategy*; the EQF;
- the National Qualifications Framework of Ukraine (Resolution of the Cabinet of Ministers No. 1341 and subsequent amendments);
- the Licensing Conditions for the Provision of Educational Activity (Resolution of the Cabinet of Ministers No. 1187);
- the Laws of Ukraine *On Education, On Higher Education, On Innovation Activity*;
- the EU-Ukraine Association Agreement;
- the *Strategy for the Development of Export of Agricultural, Food and Processing Industry Products of Ukraine until 2026*.

Quality, Accreditation, and Monitoring Mechanisms. For the sustainable implementation of changes, it is necessary to synchronise internal quality assurance systems with external accreditation procedures. A multi-level monitoring framework is proposed:

- course level is assessment rubrics aligned with LOs, mandatory portfolios and artefacts (code, models, test benches, LCA reports);
- programme level is independent stakeholder reviews, audits of practices and R&D sprints, verification of equipment relevance;
- university level is annual public analytical reports on the achievement of indicators, open data on employment and career progression.

Such approaches are consistent with the requirements of transparency and accountability embedded in European standards and the norms of Ukrainian legislation.

The “teacher-mentor” model presupposes the integration of pedagogical expertise, research competences, and the ability to manage engineering projects. An annual professional development plan is recommended: internships at European universities and enterprises, participation in grant-funded projects, development of authorial courses, micro-qualifications in production network cybersecurity, occupational safety, and eco-design. For practising engineers engaged in teaching, flexible contracts, joint supervision of projects, co-authorship of publications, and a system of recognition of results within company reports are envisaged.

Basic Infrastructure: computer laboratories, CAE/CFD/CAD, measurement complexes, test benches, unmanned platforms, and data servers. Funding is ensured through a combination of state and grant resources (including Horizon Europe), industrial contracts, and co-financing mechanisms with local communities and donors. A mechanism of service contracts is being introduced: laboratories provide enterprises with services in testing, metrology, and digital

auditing, thereby generating resources for equipment renewal and the support of scholarship programmes.

In the context of the growing role of cyber-physical systems, issues of cybersecurity in production processes, protection of telemetry data, and safeguarding of trade secrets are becoming increasingly pertinent. Educational programmes must incorporate modules on IIoT threats and protection, secure integration of PLC/SCADA, access policies, vulnerability management, and incident response. The ethical component encompasses the responsible use of data, prevention of “greenwashing”, transparent declaration of environmental indicators, and accurate risk assessment.

Example of a Curriculum Structure (fragment):

- Semesters 1–2: sustainable and digital engineering, mechatronics, GIS/drones, R&D sprint.
- Semesters 3–4: PLC/SCADA, CAD/CAM/PLM, LCA, Farm-to-Fork Engineering module, internship and thesis project.

Impact Assessment (KPIs). Educational: proportion of courses with a project component (>70%), percentage of students who have completed prototypes or software (>40%), number of micro-qualifications per student (≥ 2 /year). Research: joint university-enterprise publications, intellectual property applications, participation in international projects. Production: reduction in specific energy/pesticide consumption, decreased downtime, increased productivity. Environmental: reduction of emissions and waste, introduction of closed-loop water practices, share of organic plots in case studies.

The risk of resource insufficiency is mitigated by phased procurement and service contracts with businesses; staff-related risk—through mentoring programmes and dual “teacher–engineer” positions; regulatory risk—through systemic dialogue with the Ministry of Education and Science and the National Agency for Higher Education Quality Assurance, as well as pilot accreditations; institutional risk—through the formalisation of partnerships and a transparent intellectual property allocation system. A reserve of time is provided for equipment adaptation and the integration of safety protocols.

Integrated dual trajectories are expected to form local innovation ecosystems:

- universities become centres of expertise,
- the proportion of processing and precision agriculture services increases,
- community competitiveness is strengthened.

Discussion

In the conducted study, the regulatory frameworks of the EU and Ukraine, the educational models of the Czech Republic, as well as the possibilities of their implementation in the Ukrainian context were analysed. The findings indicate that the transformation of engineering education is impossible without a comprehensive revision of existing approaches to the organisation of the educational process. Foremost is the integration of practice-oriented learning methods, close cooperation between universities and business, and a focus on competences defined by the European Qualifications Framework.

At the same time, questions arise concerning the resource and staffing provision of the proposed changes. The Czech experience demonstrates the effectiveness of short industrial

sprints and joint laboratories; however, for Ukraine, challenges remain in financing equipment, training a new type of lecturer, and establishing mechanisms for the protection of intellectual property. Furthermore, the integration of digital technologies into the educational process (IoT, SCADA, digital twins) requires not only technical infrastructure but also the cultivation of a culture of data use, their protection, and an ethical attitude towards outcomes.

The issue of balancing academic training and industrial practice is also subject to debate. On the one hand, universities must prepare specialists with a broad worldview and fundamental knowledge; on the other hand, the labour market demands “quick solutions” and readiness to work with specific equipment and technologies. The dual model of “university—R&D—production” may serve as a compromise, but its scaling requires regulatory flexibility and a sustained dialogue among all participants in the educational process.

Thus, the proposed approaches open new opportunities for the development of Ukrainian engineering education, yet they necessitate further discussions and clarifications. In particular, it is important to address the issues of resource support, the integration of micro-credentials, the assessment of learning outcomes, and the role of international partnerships. Solving these problems will make it possible to move from declarations to real practices and ensure the training of engineers capable of working within the conditions of the European market and global challenges.

Conclusion

Modern European policy in sustainability and innovation is shaping a fundamentally new profile of the engineer. This is no longer merely a professional capable of producing technical drawings or maintaining systems. Today, the engineer is regarded as a highly qualified specialist able to design, model and validate technological solutions, taking into account the entire product life cycle, its digital footprint, compliance with environmental requirements and regulatory standards. Within such a paradigm, key significance is attached to competences that integrate technical knowledge with managerial, environmental and digital skills.

The example of the Czech Republic demonstrates that the most effective models of training are those which combine academic education with real industrial practice. Project-based learning, the establishment of joint university-business laboratories, and the organisation of short but intensive R&D sprints focused on the needs of enterprises make it possible to update curricula rapidly and to prepare engineers equipped with “new wave” skills. Owing to this practice-oriented model, student projects are more readily transformed into prototypes, start-ups or fully-fledged innovative solutions, while graduates integrate more easily into the labour market.

For Ukraine, this experience is of exceptional relevance. The national legal and regulatory framework already contains the instruments required to scale up such approaches. In particular, the NQF, harmonised with the EQF, ensures the “readability” of learning outcomes for European employers. Licensing conditions, the Laws of Ukraine *On Education*, *On Higher Education*, *On Innovation Activity*, as well as the provisions of the EU-Ukraine Association Agreement, establish the legal framework for the integration of dual programmes, international projects, and educational-research partnerships.

The successful implementation of European practices requires a systemic approach. First and foremost, curricula need to be redesigned with a focus on developing transversal

competences in sustainable engineering, digital engineering, product life cycle management, innovative entrepreneurship, and the safety of production processes. Special attention should be devoted to the integration of modules on intelligent technologies: sensor systems, drones, satellite monitoring, digital twins, PLC/SCADA platforms, as well as methods of machine learning.

A crucial factor is the establishment of a sustainable dialogue between universities, business and the state. Only within a partnership format can the relevance of educational outcomes, access to modern equipment, opportunities for placements, and project tasks aligned with real industrial needs be guaranteed. Equally important is internationalisation: joint programmes with EU universities, participation in Horizon Europe consortia, mutual recognition of credits, international publications and dual degree schemes create favourable conditions for integrating Ukrainian engineers into the global market.

It is also essential to emphasise the importance of cultivating a culture of measurable outcomes. Contemporary approaches require not only the declaration of aims or competences, but also their clear operationalisation through indicators: the number of prototypes, start-ups, joint publications, implemented case studies, reductions in energy consumption, and ecological impact. Precisely this culture of evidence and transparency underpins stakeholder trust and enhances the effectiveness of educational and research systems.

Thus, the key conditions for success may be outlined as follows: the renewal of curricula “for the tasks of the future”; continuous dialogue with business and industrial partners; internationalisation through educational and scientific consortia; and the formation of a culture of measurability and accountability for outcomes. The implementation of these conditions will enable Ukraine to prepare “new wave” engineers-specialists who not only possess advanced technical knowledge, but are also capable of responding to global challenges related to sustainability, digitalisation and innovation.

Conflict of Interest

The author declares that there is no conflict of interest.

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