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USING ENERGY-EFFICIENCY PEDAGOGICAL TECHNOLOGIES IN PROFESSIONAL TRAINING OF FUTURE CONSTRUCTION WORKERS: EU EXPERIENCE

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Abstract

Relevance. The construction sector is central to Europe's climate and energy targets, while skilled workers are essential for delivering energy-efficient buildings. In Ukraine, integrating energy-efficiency pedagogical technologies (EEPT) into vocational education and training (VET) is urgent to support post-war reconstruction, align with EU standards, and strengthen national energy security.

Aim: To examine the use of EEPT in professional training of construction workers in the EU and explore how these approaches can be adapted and implemented in Ukraine's vocational education system.

Methods: A three-step comparative-adaptive approach was applied, including competence mapping of EU and Ukrainian VET standards, a review of EU teaching methods suitable for Ukrainian vocational schools, and analysis of implementation pathways through pilot projects, partnerships, and curriculum updates.

Results: Competence mapping revealed that EU energy-efficiency standards cover skills in building physics, envelope performance, energy-efficient system installation, diagnostics, and site organisation. Ukrainian VET currently provides limited practical experience in these areas. EU projects, such as MEnS and VET4LEC, demonstrate that combining classroom instruction with hands-on practice and digital tools (BIM, VR, AR) enhances learner competence and engagement. Phased implementation in Ukraine, including teacher training, pilot projects, and curriculum modernisation, is feasible and can progressively align VET outcomes with European standards.

Conclusions: Adopting EU-based EEPT offers a pathway for modernising Ukrainian vocational education, fostering a workforce capable of delivering energy-efficient construction projects, supporting sustainable reconstruction, and promoting alignment with European best practices. Future research should assess the effectiveness of EEPT in Ukrainian schools to inform scalable implementation.

Keywords: *energy efficiency, vocational education and training, construction workers, energy-efficiency pedagogical technologies, Ukraine, European Union, curriculum modernisation.*

Introduction. The construction industry plays a significant role in achieving climate and energy goals in leading EU countries. Buildings account for a significant share of energy consumption and emissions, and skilled specialists are important agents for implementing comprehensive renovation, construction of Near-Zero Energy Buildings (NZEB), ensuring airtightness, high-quality thermal insulation, and the implementation of smart management systems. In the context of Vocational Education and Training (hereinafter – VET), EU countries are systematically adapting educational programs, pedagogical approaches, and assessment systems to improve eco-oriented competencies as a primary outcome of the

professional training of future skilled workers in the construction industry (Cedefop, 2023).

For Ukraine, where construction is an important factor in economic recovery, the integration of eco-oriented pedagogical technologies into VET is particularly urgent. The country must simultaneously align its actions with the goals of the European Green Deal and strengthen its own energy security and resilience. The war has further underscored the need for rapid yet sustainable recovery, making energy-efficient construction skills critically important. The implementation of eco-oriented pedagogical technologies in the Ukrainian VET system can help form a modern workforce capable of meeting European standards and national priorities through the updating of educational programs, professional development of teachers, and partnerships with industry. Drawing on EU experience, Ukraine can accelerate reforms that are key to post-war recovery and long-term energy independence.

Sources. This article analyzes contemporary scientific sources to substantiate the integration of eco-oriented pedagogical technologies into the professional training of future skilled workers. At the European level, key policy frameworks, such as the Energy Performance of Buildings Directive (European Commission, 2024), the European Green Deal (European Commission, 2019), and the Renovation Wave Strategy (European Commission, 2020), set ambitious requirements for reducing emissions and improving the energy efficiency of buildings. These initiatives highlight the central role of skilled construction workers and serve as benchmarks for defining competencies in the fields of airtightness, thermal insulation quality, and the installation of modern building systems.

In Ukraine, legislative initiatives such as the Law "On Energy Efficiency" (Verkhovna Rada of Ukraine, 2021), the National Recovery Plan (Cabinet of Ministers of Ukraine, 2023), and obligations arising from EU integration are powerful drivers of reform. They emphasize a dual task: restoring damaged infrastructure and modernizing the VET system to comply with European standards.

The experience of European VET offers practical models for adaptation. Dual training systems, where theoretical learning is combined with practice in the workplace, demonstrate how competencies can be strengthened through practical experience (Ertelt et al., 2021). Partnerships between educational institutions and industry, as well as workshops supported by manufacturers, show how effective collaboration can directly contribute to the creation and development of new digital technologies and learning materials (Esangbedo et al., 2024). Practice-based learning modules, such as pilot renovation projects, demonstrate how real construction sites can serve as learning laboratories (Schwede et al., 2025).

Conversely, the Ukrainian VET system currently faces a number of limitations. Many institutions operate under outdated curricula that do not reflect modern energy efficiency requirements (Herasymyk-Chernova et al., 2020). At the same time, the lack of technical equipment, such as airtightness testing systems, thermal imagers, and other diagnostic tools, limits opportunities for practical training. Furthermore, teachers need to upgrade their qualifications to teach competencies corresponding to European standards.

Finally, digital and didactic innovations, such as Building Information Modeling (BIM), Virtual and Augmented Reality (VR/AR) applications, and performance diagnostic systems, offer realistic tools to bridge these gaps (Elgewely et al., 2021). Their gradual implementation in Ukrainian VET education can visualize energy performance for students, providing a basis for aligning learning outcomes with European standards and supporting Ukraine's broader recovery and integration goals.

The purpose of the article is to research the use of eco-oriented pedagogical technologies in the professional training of future skilled workers in the construction industry in EU countries. The article outlines a competence map associated with key professional tasks, highlights effective teaching methods, and identifies favorable conditions for their application. Based on these findings, recommendations have been developed for the adaptation and implementation of such approaches in the VET system of Ukraine.

Research methods. The article applies a three-stage comparative-adaptive approach, including: 1) "mapping" of competencies according to EU and Ukrainian vocational education standards; 2) a review of eco-oriented pedagogical

technologies applied by European colleagues that can be implemented in Ukrainian vocational education and training institutions; 3) an analysis of pathways for their implementation through pilot projects, partnerships, and the updating of educational programs.

Results and discussion. The conducted comparative-adaptive analysis demonstrates important conclusions regarding the integration of eco-oriented pedagogical technologies into the professional training of future skilled workers in the construction industry in Ukraine. Studying EU practices allows identifying both gaps in the Ukrainian VET system and opportunities for targeted interventions that will facilitate the development of professional competencies in the field of energy-efficient construction.

Competence mapping proves that EU standards in the field of energy efficiency cover a wide range of skills, including building physics, building envelope characteristics, installation of energy-efficient systems, conducting diagnostic tests, and construction site organization (Kozlovska et al., 2023). In Ukraine, although certain theoretical knowledge is present in VET programs, practical competencies remain insufficiently developed, especially in the fields of airtightness testing, diagnostics using thermal imagers, and the integration of "smart" systems. These skills are critically important for ensuring the quality and efficiency of modern energy-efficient buildings.

For example, the EU-funded MEnS project developed specialized training for architects and engineers to retrofit housing stock in accordance with Near-Zero Energy Building (NZEB) standards (CORDIS, 2018). The initiative was aimed at equipping construction managers with practical skills in the design, operation, and maintenance of energy-efficient facilities, serving as a reliable model for adapting Ukrainian educational programs by combining theoretical and practical competencies in the sphere of energy efficiency. Such projects demonstrate that combining knowledge with practical skills significantly increases workforce readiness and supports broader sustainable development goals.

A review of pedagogical technologies reveals several EU approaches particularly suitable for integration into the VET system in Ukraine. Dual training models, combining classroom learning with on-the-job practice, consistently ensure a high level of competence and skill retention among students (Pilz & Wiemann, 2021). Within the framework of the VET4LEC project, requirements for vocational education and elements of low-energy construction necessary for training a workforce capable of implementing NZEB projects were investigated (Janssen, 2019). In particular, such an initiative highlights the effectiveness of combining theoretical learning with practical experience, as students engaged in practical exercises gain a deeper understanding of energy-efficient construction principles.

Furthermore, digital tools, including Building Information Modeling (BIM), Virtual (VR), and Augmented (AR) Reality, facilitate the development of inquiry-based learning, enabling students to visualize building performance, simulate diagnostic procedures, and assess the impact of construction decisions in a controlled environment (Khan et al., 2024). The ENERGE framework regarding energy efficiency in schools demonstrates how these digital tools can be systematically integrated into VET, improving learning outcomes, increasing motivation, and ensuring the acquisition of skills corresponding to modern energy efficiency standards (Brychkov et al., 2023).

Implementation pathways for Ukraine envisage a phased and adaptive approach. In the short term, pilot projects can be implemented in selected VET institutions, supplemented by targeted teacher training and partnerships with construction companies and equipment manufacturers. Such collaboration will provide both technical expertise and access to modern equipment, allowing for practical training without the need for large initial investments. In the medium term, educational programs can be revised to integrate eco-oriented pedagogical technologies into relevant training courses, and assessment standards can be formalized in accordance with EU competence frameworks, ensuring that graduates are assessed against clear and measurable criteria. Over time, such interventions can gradually transform Ukrainian VET, creating a workforce capable of implementing energy-efficient construction projects that meet both national priorities and EU standards.

Overall, EU experience demonstrates that structured, practice-oriented, and technology-driven learning forms skilled professionals capable of effectively combining theoretical knowledge with practical skills. Through careful planning and strategic adaptation of these approaches, the Ukrainian VET system can replicate similar results, shaping a new generation of builders capable of supporting sustainable reconstruction, improving energy efficiency in the built environment, and bringing Ukraine's construction sector closer to European best practice standards.

Conclusions. The integration of eco-oriented pedagogical technologies into the VET system is necessary for forming a skilled workforce capable of meeting both Ukrainian and European construction standards. Competence mapping confirms that European standards cover a wide range of skills, particularly from building physics and building envelope characteristics to the installation of energy-efficient systems and conducting diagnostic tests. Currently, the VET system in Ukraine provides certain theoretical knowledge, but practical skills, especially in the fields of airtightness testing, thermal imaging diagnostics, and the integration of "smart" systems, require substantial improvement.

EU experience, particularly the MEnS and VET4LEC projects, shows that combining classroom learning with on-the-job practice, supported by digital tools such as BIM, VR, and AR, effectively develops professional competence in the field of energy-efficient construction. These approaches increase student engagement, knowledge retention, and readiness to apply skills in real-world conditions. The ENERGE framework additionally demonstrates how digital and inquiry-based methods can be systematically integrated into VET educational programs to enhance learning effectiveness.

For Ukraine, a phased and adaptive strategy for implementing eco-oriented pedagogical technologies is recommended. Short-term measures include pilot projects in selected VET institutions, targeted teacher training, and partnerships with construction companies and equipment manufacturers to ensure expertise and access to modern tools. Medium-term actions involve revising educational programs to integrate eco-oriented pedagogical technologies into several courses and formalizing assessment standards in accordance with EU competence frameworks. Gradually, such measures can transform the Ukrainian VET system, creating graduates capable of implementing energy-efficient construction projects that correspond to both national priorities and European standards.

For the purpose of effective implementation of eco-oriented pedagogical technologies, it is proposed to: 1) modernize educational programs by including both theoretical and practical competencies in energy efficiency; 2) implement professional development programs for teachers to strengthen teaching methodology and the use of digital tools; 3) develop pilot projects and partnerships with industry to provide practical experience with modern construction technologies; 4) integrate digital technologies such as BIM, VR, and AR to simulate real-world energy-efficient construction scenarios; and 5) apply a phased approach with formalized assessment standards for monitoring and measuring student competencies.

Thus, the implementation of eco-oriented pedagogical technologies based on positive aspects of European experience offers a practical pathway for modernizing the Ukrainian vocational education system. By combining theory, practice, and technology-driven learning, Ukraine can form a workforce capable of supporting sustainable reconstruction, improving energy efficiency in the built environment, and bringing the construction sector closer to European best practices.

Prospects for further research lie in substantiating the effectiveness of eco-oriented pedagogical technologies in VET institutions in Ukraine, particularly in the context of the professional development of teachers, the implementation of digital tools, and the realization of relevant projects.

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ЗАСТОСУВАННЯ ЕКООРІЄНТОВАНИХ ПЕДАГОГІЧНИХ ТЕХНОЛОГІЙ У ПРОФЕСІЙНІЙ ПІДГОТОВЦІ МАЙБУТНІХ КВАЛІФІКОВАНИХ РОБІТНИКІВ БУДІВЕЛЬНОЇ ГАЛУЗІ: ДОСВІД ЄС

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Реферат:

Актуальність: будівельна галузь є ключовою у досягненні кліматичних та енергетичних цілей, зокрема у країнах ЄС; кваліфіковані робітники відіграють важливу роль у реалізації енергоефективного зеленого будівництва; в Україні інтеграція екоорієнтованих педагогічних технологій у систему професійної (професійно-технічної) освіти є нагальною для підтримки післявоєнного відновлення, гармонізації з європейськими стандартами та посилення національної енергетичної безпеки.

Мета: проаналізувати використання екоорієнтованих педагогічних технологій у професійній підготовці майбутніх кваліфікованих робітників будівельної галузі у країнах ЄС та визначити шляхи адаптації й впровадження таких підходів у систему професійної (професійно-технічної) освіти України.

Методи: застосовано трьохетапний порівняльно-адаптивний підхід, що включає: 1) «картування» (mapping) компетентностей за стандартами професійної освіти ЄС та України; 2) огляд екоорієнтованих педагогічних технологій, застосовуваних європейськими колегами, які можуть бути реалізовані в українських закладах професійної (професійно-технічної) освіти; 3) аналіз шляхів їхнього впровадження завдяки пілотним проєктам, партнерствам та оновленню освітніх програм.

Результати. Картування компетентностей засвідчило, що європейські екоорієнтовані стандарти охоплюють навички з будівельної фізики, характеристик будівельного огородження, монтажу енергоефективних систем, діагностики та організації робочих процесів на будівельному майданчику. Українські заклади професійної (професійно-технічної) освіти наразі пропонують обмежений практичний досвід у цих галузях. Проєкти ЄС, такі як MEnS та VET4LEC, демонструють, що поєднання аудиторного навчання з практичними вправами та цифровими інструментами (BIM, VR, AR) підвищує компетентність та залученість студентів. Поетапне впровадження екоорієнтованих педагогічних технологій в Україні, включно з підвищенням кваліфікації

викладачів, пілотними проєктами та модернізацією освітніх програм, є можливим і поступово дозволяє узгодити результати професійної (професійно-технічної) освіти з європейськими стандартами.

Висновки: адаптація екоорієнтованих педагогічних технологій на основі досвіду ЄС створює можливості для модернізації української професійної освіти, підготовки кваліфікованих фахівців, здатних реалізовувати енергоефективні будівельні проєкти, підтримувати стале відновлення та наближати будівельну галузь України до найкращих європейських практик; подальші дослідження мають оцінити ефективність екоорієнтованих педагогічних технологій в українських закладах освіти для забезпечення їхнього системного впровадження.

Ключові слова: *енергоефективність, професійна освіта, фахівець будівельної галузі, екоорієнтовані педагогічні технології, Україна, ЄС, модернізація освітніх програм.*

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