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PEDAGOGICAL CONDITIONS FOR THE DEVELOPMENT OF ENTREPRENEURIAL COMPETENCE IN FUTURE RENEWABLE ENERGY SYSTEM INSTALLATION AND MAINTENANCE TECHNICIANS

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Abstract

Relevance Ukraine is currently in an active phase of energy transition, the strategic trajectory of which is determined by European integration commitments under the European Green Deal and national priorities for alternative energy development. Prolonged warfare (ongoing hostilities) and massive strikes on centralized energy infrastructure have rendered this transition imperative (left no alternative to this transition): distributed generation, local energy solutions, and the utilization of alternative energy sources in every community have become a prerequisite for the state's energy resilience, rather than merely a strategic choice. The urgent need for power supply decentralization and the growing demand for alternative energy system installation from households, local communities, small businesses, and enterprises of various ownership forms expand the scope of professional activity of future technicians, which increasingly acquires the features of independent management (independent entrepreneurship) within local energy markets. Such a transformation of professional requirements naturally shifts the approaches to specialist training: entrepreneurial competence is turning from a desirable addition to a vocational qualification into its mandatory, industry-driven (sector-specific) component. Entrepreneurial competence as a component of vocational training is reflected in the current educational programs of vocational education institutions; however, its development is mostly implemented in a generalized format, failing to sufficiently consider the specifics of technical professions in general and the sectoral context of alternative energy in particular: market mechanisms of "green" generation, regulatory features of the energy market, the economics of distributed generation projects, communication with various clients (service consumers), etc. As a result, graduates possess general notions of entrepreneurial activity that do not translate into a readiness to act within the sectoral professional environment. Addressing the outlined educational problem requires the substantiation of pedagogical conditions for developing the entrepreneurial competence of future technicians. Their interconnected implementation in the educational process will ensure its formation as an industry-driven component of vocational training, enabling independent professional activity within the specific realities of alternative energy.

Purpose: to theoretically substantiate the pedagogical conditions for developing entrepreneurial competence in future renewable energy system installation and maintenance technicians during their vocational education, and to reveal the nature of the interrelations between these conditions, which forms the basis for their joint implementation in the educational process.

Methods: the study of scientific literature (scientific heritage) through analysis and synthesis made it possible to clarify the content of the concept of "pedagogical conditions" in the context of developing the entrepreneurial competence of alternative energy specialists and to identify under-researched aspects of the problem; a systems approach ensured that pedagogical conditions were viewed as an integrated didactic complex within which each condition is functionally linked to the others; methods of generalization and concretization were applied to transition from conceptual propositions to the operational characteristics of the identified conditions; the priority of pedagogical conditions was determined based on the results of expert evaluation and ranking.

Results: the content of the concept of "pedagogical conditions for the development of entrepreneurial competence" has been clarified in relation to the sectoral context of alternative energy, which allowed for its specification for alternative energy-related professions; pedagogical conditions oriented toward forming the entrepreneurial competence of future specialists in accordance with the realities of local energy markets and dynamic changes in the specified sector of the economy have been theoretically substantiated; the inter-component relationships between pedagogical conditions have been revealed, which cause their mutual reinforcement in the educational process and determine their simultaneous implementation as a prerequisite for the effective development of entrepreneurial competence in future renewable energy system installation technicians.

Conclusion: The theoretically substantiated pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians are based on the understanding of this competence as an industry-driven construct (formation), the content and formation methods of which are determined by the specifics of professional activity in the field of alternative energy. The identified pedagogical conditions encompass the key components of the educational process and, in their entirety, ensure the transition of learners from an introduction to the basics of entrepreneurship to independent entrepreneurial activity in a real industry environment. The substantiated conditions are interdependent: their effectiveness is achieved only through simultaneous implementation, which defines them as an integrated didactic complex rather than a set of independent factors. The results obtained create a foundation for updating educational programs and curriculum documentation (instructional planning documentation) for training renewable energy system installation technicians in vocational education institutions, developing methodological recommendations for teaching staff, and further designing a methodology for developing the entrepreneurial competence of the specified specialists.

Keywords: *vocational education, pedagogical condition, vocational education institution (VET institution), competence-based approach, entrepreneurial competence, alternative energy, industry-driven nature (sectoral dependency), entrepreneurial proactivity, technological mobility, subjective position (agentic position), project-based activity.*

Introduction. The development of renewable energy is one of the defining trends of the modern global economy; however, for Ukraine, this process has acquired a distinct dimension characterized by unprecedented urgency. Systematic strikes on centralized energy infrastructure resulted in the loss of approximately 10 GW of generating capacity in 2024 alone across thirteen massive attacks (Ministry of Energy of Ukraine, 2024), while the share of available generation plummeted to a quarter of its pre-war level (Razumkov Centre, 2024). Under these circumstances, distributed generation based on alternative energy sources has ceased to be a matter of strategic choice and has transformed into a vital instrument for community energy resilience: decentralized power supply meets the critical needs of households, social institutions, and enterprises during prolonged blackouts. Faced with an unstable energy infrastructure and a systematic increase in electricity costs, business entities and private households are increasingly allocating financial resources toward

securing their own energy independence. This allows them to minimize operational risks associated with emergency power outages and to safeguard production processes and daily life from the adverse effects of unpredictable fluctuations in energy tariffs. The strategic trajectory of this transition is defined by national priorities for sectoral development and European integration commitments within the framework of the European Green Deal.

The response to this challenge has been the rapid expansion of the small-scale distributed generation segment. In 2024 alone, businesses and households commissioned 800–850 MW of new solar capacity at their own expense (Solar Energy Association of Ukraine, 2025), with a significant portion of these installations carried out precisely by private households. In 2025, construction paces doubled, and the volume of solar panel imports over a nine-month period reached a capacity equivalent

to two nuclear power units (Atmosfera, 2025). This represents not merely a technological but a structural transformation of the energy landscape: power generation is shifting from large-scale energy complexes to local systems within territorial communities, small businesses, and individual households, thereby shaping numerous local energy markets.

This transformation fundamentally alters the core professional activities of a renewable energy system installation and maintenance technician. In a centralized energy supply model, the specialist operated within a large enterprise, performing regulated technical operations within a clearly defined functional scope. Conversely, in a local market, they carry out professional activities as an independent economic agent, shifting the very nature of their labor. The diversification of the energy market generates demand for a new type of specialist a "techno-entrepreneur" for whom entrepreneurial activity in the field of renewable energy is not an isolated function appended to a technical qualification, but rather a primary form of professional practice.

The training of these specialists is provided by vocational education institutions whose educational programs incorporate an entrepreneurial component designated as a core competency. However, entrepreneurial competence is inherently context-dependent: it does not exist in isolation from the industry realities in which it must be applied, and it cannot be mechanically transferred from a general entrepreneurship course to a specific professional practice without a significant loss of efficacy. A specialist who is aware of general business principles but lacks an understanding of how the renewable energy market functions, the state support mechanisms by which it is regulated, and how the expectations of a private homeowner differ from those of a local government authority remains an entrepreneur in name only.

Hence, a scientific problem arises: there is a contradiction between the actual professional activities in alternative energy which require industry-specific entrepreneurial readiness and the generalized nature of entrepreneurial training provided in vocational education institutions. Overcoming this contradiction requires the substantiation of pedagogical conditions whose

implementation within the educational process ensures the transformation of general entrepreneurial knowledge into an industry-specific readiness of the future technician for individual professional activity within the realities of alternative energy.

Sources. The essence of the concept of "pedagogical conditions" has been thoroughly examined in the scientific literature, where it is interpreted from various perspectives. In the "Dictionary-Reference Book on Vocational Pedagogics" edited by A. Semenova (2006), pedagogical conditions are defined as circumstances upon which an integrated, productive process of vocational training depends and within which it occurs, mediated by the activity of the individual. A. Lytvyn (2018) treats them as a complex of specially designed, system-forming factors influencing the external and internal circumstances of the educational process and the personal attributes of its participants. Ye. Khrykov (2022) emphasizes the fundamental difference between pedagogical conditions, which are purposefully created by an educator, and objectively existing factors, while O. Sahach (2020), through a comparison of definitions, delineates the concepts of "condition," "pedagogical conditions," and "organizational-pedagogical conditions." In studies directly linking pedagogical conditions to entrepreneurial themes, I. Zinkova (2020) views them as a set of external and internal factors that combine specially modeled content, forms, methods, and means of educational activity, whereas O. Zemka (2017) regards them as an indivisible unity of pedagogical process measures that ensure the achievement of the required level of competency development. Despite differences in emphasis, these approaches are unified by a systemic understanding of pedagogical conditions as a purposefully constructed, interconnected entity rather than a mere sum of isolated factors.

The issues surrounding the development of entrepreneurial competence within the vocational education system have been reflected in domestic scientific discourse, where they are examined both at the level of the strategic context of sectoral functioning and as the immediate subject of research. At the strategic level, V. Radkevych, O. Radkevych, and M. Pryhodii (2022) analyzed the challenges facing vocational education and the

associated threats to national interests, economic security, and the energy independence of the state. More specifically, the content, structure, pedagogical conditions, forms, and methods of developing the entrepreneurial competence of future specialists are elucidated in the works of domestic scholars such as I. Hrytsenok (2023), L. Yershova, D. Zakatnov, and O. Titova (2022), O. Zamferesko (2019), H. Matukova (2015), and A. Moldovan (2021).

The systemic nature of pedagogical conditions is corroborated by contemporary domestic research on entrepreneurial competence within the vocational education system. V. Kushnir (2022) defines the pedagogical conditions for the development of entrepreneurial competence as a "content characteristic of the components of the pedagogical system of vocational education, which reveals the content, methods, forms, tools, and reflection of future specialists," thereby viewing pedagogical conditions as integrated components of the pedagogical system of vocational education. L. Shesterikova (2023) substantiates the pedagogical conditions for the development of entrepreneurial competence as an integrated complex of measures which, in unity with the developed model and the methodology of their implementation, enables the achievement of expected educational outcomes, thereby asserting the inseparability of pedagogical conditions from the method of their introduction into the educational process. In a study by V. Storozhuk (2026), the pedagogical conditions for forming entrepreneurial competence emerge as an inherent component of an integrated model of project-oriented learning that integrates target, methodological, content, activity-technological, and result-evaluation blocks. Common to these approaches is the consideration of pedagogical conditions not as a catalog of independent factors, but as integrated components of a comprehensive didactic design working toward a common outcome.

In the international scientific arena, J. Hessels and W. Naudé (2019) proposed a synthetic definition of entrepreneurship as a driver of economic development, noting that the fields of entrepreneurship and development economics had long been elaborated in isolation and have only recently begun to intersect. Crucial to our study, the understanding of entrepreneurship as a holistic

competence is enshrined in the European Entrepreneurship Competence Framework (EntreComp, 2016), which interprets it through interconnected areas: ideas and opportunities, resources, and into action. H. Cassean, J. Vanevenhoven, E. Liguori, and D. Winkel (2015) substantiated the necessity of shifting entrepreneurial education from classroom-bound activities toward reflection, real-world experience, and action.

At the same time, an analysis of existing research reveals that a specific aspect of the problem remains under-researched (insufficiently developed). The vast majority of studies on entrepreneurial competence focus on higher education, economic or artistic professions, and the service sector, while the specifics of its development in future technical specialists remain on the periphery of scholarly attention. The sectoral context of alternative energy, with its inherent technological dynamics, regulatory volatility (regulatory mutability), and local market structures, has not yet found a holistic reflection in the substantiation of pedagogical conditions for training relevant specialists, which underscores the necessity of this study.

The purpose of the article is to identify and theoretically substantiate the pedagogical conditions whose implementation within the educational process of vocational education institutions ensures the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians, provided they are simultaneously implemented as an integrated didactic complex. Achieving this goal involves addressing several objectives: clarifying the content of the concept of "pedagogical conditions for the development of entrepreneurial competence" in relation to the sectoral context of alternative energy; identifying and theoretically substantiating the pedagogical conditions for developing this competence within the educational process of vocational education institutions; revealing the nature of the interrelations between the identified pedagogical conditions that necessitate their simultaneous implementation in the educational process; and outlining the prospects for the practical implementation of the substantiated pedagogical conditions and further research.

Research Methods. Addressing the set objectives relies on a combination of theoretical methods, the selection of which was dictated by the study's purpose and its theoretical and analytical nature. The information base of the study comprised: domestic and foreign scientific works on the issues of pedagogical conditions and entrepreneurial competence development published in monographs, dissertations, and peer-reviewed (professional) or international journals; materials of the European Entrepreneurship Competence Framework (EntreComp); regulatory and legal acts governing the functioning of the vocational education system in Ukraine and defining the strategic foundations for alternative energy development; and analytical materials from the Ministry of Energy of Ukraine, the Solar Energy Association of Ukraine, and other industry institutions reflecting the specific development of the alternative energy sector. Methods of analysis and synthesis were used to process this source base, which enabled the clarification of the concept of "pedagogical conditions" within the context of entrepreneurial competence development in alternative energy specialists and the identification of under-researched aspects of the problem. A systems approach ensured that the pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians were examined in the unity of their functional connections and characteristics, allowing for the interconnected nature of the identified conditions and the necessity of their joint implementation in the educational process of vocational education institutions to be taken into account. Methods of generalization and concretization were applied to transition from conceptual propositions regarding pedagogical conditions to the operational characteristics of each identified condition in accordance with the sectoral features of training alternative energy specialists. The priority of the pedagogical conditions was determined based on the results of expert evaluation and ranking.

Results and Discussion. The development of entrepreneurial competence in future renewable energy system installation and maintenance technicians is an industry-driven (sector-specific) process that requires the specification of the concept

of "pedagogical conditions" in accordance with the features of a specialist's professional practice in the new energy reality. Drawing upon the understanding of pedagogical conditions generalized in the literature review as a purposefully constructed, interconnected framework (structure), we can assert that the pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians constitute purposefully constructed circumstances of the educational process that foster the development of learners' readiness for independent professional activity within the realities of local energy markets and account for the specificities of forming entrepreneurial competence amidst dynamic changes in the alternative energy sector.

This definition captures three fundamental tenets. First, pedagogical conditions are directionally constructed (purposefully targeted) components of the educational process, which aligns with the systems approach to their interpretation in domestic and international scientific literature. Second, the object of their influence is the readiness for independent professional activity, which positions entrepreneurial competence not as an isolated module of the educational program, but as an industry-driven component of professionalism, without which a specialist in the new energy reality remains an entrepreneur in name only. Third, the conditions factor in the specific features of the sectoral context: the realities of local energy markets, the regulatory environment of the energy market, and the dynamics of technological change, which prevents the proposed system from being a universal didactic template and provides it with sectoral grounding (industry embedding). Within the scope of our study, pedagogical conditions are viewed in the unity of their mutual functional links, in relations of hierarchical interdependence and simultaneous implementation in the educational process, collectively ensuring the development of entrepreneurial competence as an industry-driven component of the professional identity (professional self-awareness) of the future renewable energy system installation and maintenance technician.

The transition from a general definition to a system of specific pedagogical conditions is guided by the systems principle, according to which

pedagogical conditions are regarded not as a mechanical list of individual factors, but as an integrated didactic complex wherein each condition performs a specific function in developing entrepreneurial competence, and their collective implementation creates an educational environment capable of delivering the expected outcome. The identification of specific conditions was based on the analysis of three interconnected processes that define the current state of the alternative energy sector: energy generation decentralization, the dynamics of technological changes, and the emergence of new market niches for small business (Koliadych, 2024). Each of these processes actualizes a specific vector of pedagogical influence ranging from updating educational programs to forming the learner's readiness for autonomous professional action.

Modern entrepreneurial activity in the field of renewable energy unfolds in the format of technological entrepreneurship (tech entrepreneurship), which is based on the transformation of scientific and technological knowledge into industrially applicable solutions to create economic value (Kalach, 2024). Therefore, the entrepreneurial competence of a future renewable energy system installation and maintenance technician, accordingly, emerges not as an external superstructure (extraneous add-on) to vocational training, but as its sectorally integrated component, which is formed alongside the professional qualification and is embodied within it. This reinforces the argument in favor of the systemic nature of the pedagogical conditions for its development: they must be designed with a view to the integrity of the future specialist's professional profile (professional persona).

The identification of pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians involved two consecutive stages. At the first stage, through a theoretical analysis of psychological and pedagogical works on the substantiation of pedagogical conditions, a

conceptualization of contemporary experiences in the vocational training of these specialists, and a study of the best practices in entrepreneurial education using methods of analysis and synthesis, 12 potential pedagogical conditions were identified. These encompassed factors related to the content of vocational training, its methodological and technological tools, the personal and activity-based qualities of learners, and factors of educational environment organization. At the second stage, based on the results of expert evaluation and ranking of these conditions by academic and teaching staff of vocational education institutions and representatives of renewable energy enterprises according to the degree of their impact on forming the entrepreneurial competence of these specialists, four priority pedagogical conditions received the highest ranks and were isolated: modernization of the content of educational programs through the integration of modern entrepreneurial practices of the energy sector; application of simulation-based learning technologies with modeling of the full cycle of an energy enterprise; development of technological mobility and adaptability of learners to dynamic energy market changes through the cultivation of entrepreneurial proactivity; and the activation of students' agentic position (subjective position) through the independent design of entrepreneurial initiatives. The architecture of these conditions reflects the logic of the gradual deployment of the entrepreneurial competence development process: from forming a realistic understanding of industry specifics through the modeling of practical activities to personal-activity readiness and an autonomous, agentic position. This sequence of functional layers aligns with the logic of mastering professional activity established in vocational education pedagogy: from acquiring a knowledge base through its practical refinement to forming the specialist's personal qualities and their emergence as an autonomous agent (subject) of professional action. Let us examine the content of each identified pedagogical condition individually.

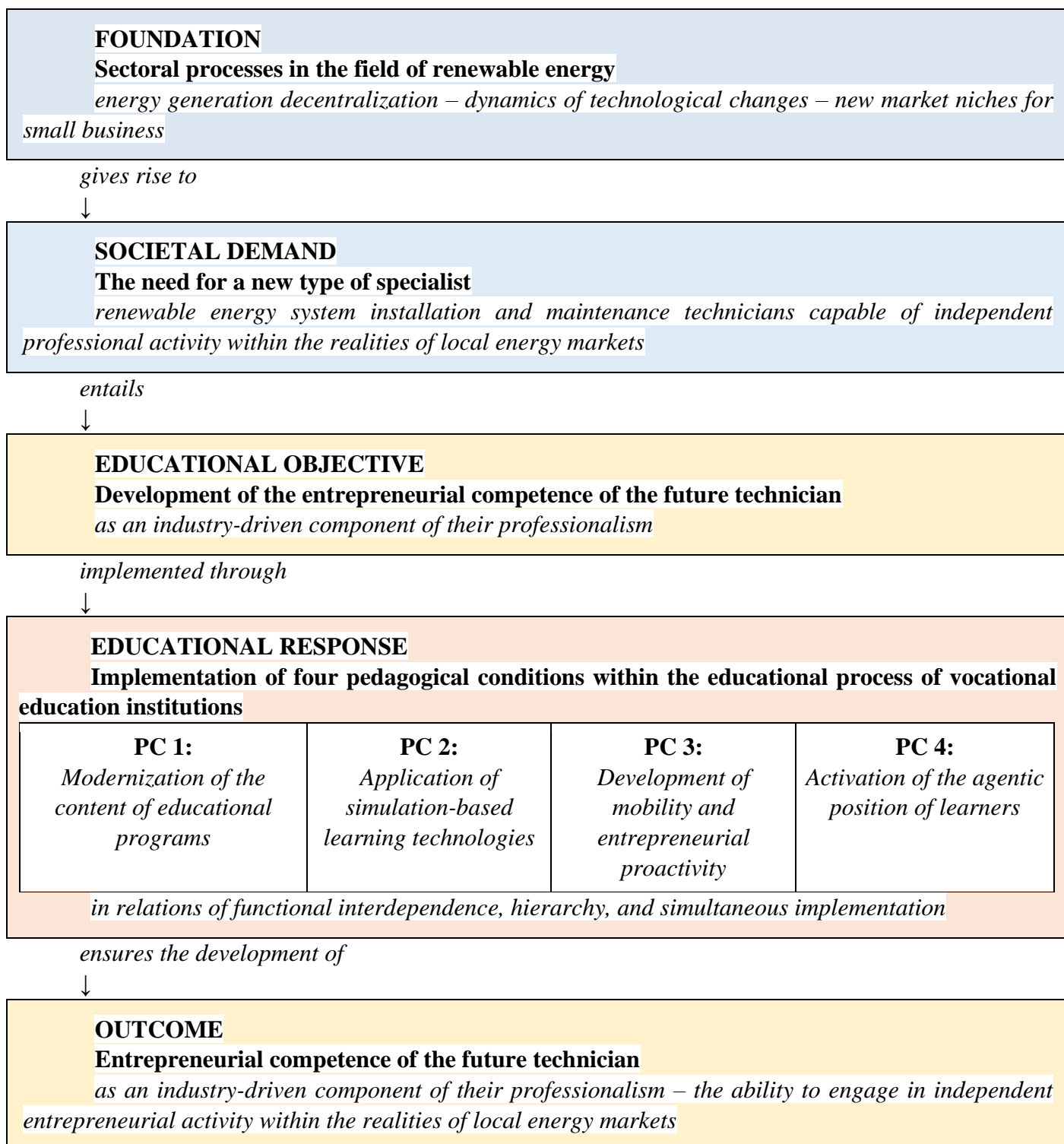


Fig. 1. Conceptual map of pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians

Among the array of identified pedagogical conditions, a foundational role is occupied by the modernization of educational program content through the integration of contemporary entrepreneurial practices of the energy sector. The primary nature of this specific condition stems from the very essence of entrepreneurial competence

development within an industry-specific context: no methodological solution achieves pedagogical efficacy when the substantive base of vocational training fails to reflect the current architecture of the energy sector, as enshrined in the Energy Strategy of Ukraine for the Period until 2050 and the National Renewable Energy Action Plan until 2030. Its core

substance lies in the purposeful inclusion of real-world case studies from energy enterprises, business models in renewable energy generation, state support mechanisms for the industry, and project financing and payback schemes into the mandatory educational components of professional and theoretical training. This ensures that theoretical knowledge and practical skills are mastered by learners in direct alignment with the entrepreneurial context in which they actually operate. Within the system of isolated conditions, the functional purpose of this condition is to provide a foundational content base, without which simulation modeling, the cultivation of proactivity, and the activation of the learner's agentic position (subjective position) are deprived of substantive meaning, devolving into the mastery of abstract forms detached from sectoral content.

The prerequisite for this modernization is a certain structural mismatch (discrepancy) between the traditionally established content of vocational training for renewable energy system installation and maintenance technicians and the contemporary reality of the energy market, which is characterized by the decentralization of generation, the active penetration of digital technologies into power system management, and the expansion of small-scale industry entrepreneurship. In studies addressing the organizational and pedagogical conditions for forming the professional competencies of skilled workers in the maintenance sector of renewable energy systems, it is emphasized that effective vocational training for this category of specialists cannot be reduced to mastering technical operations for equipment installation and maintenance; instead, it demands a modular competence-based approach that accounts for the specific functioning of the sectoral market and the entrepreneurial dimension of the profession (Petrovych & Onopriienko, 2021). This conclusion aligns with the results of contemporary labor market analyses in the energy sector, which substantiate the need for an integrative competence model combining technological, innovative, environmental, and managerial-economic competence clusters (Hrohul & Kobylianskyi, 2026). Educational practice that treats entrepreneurial activity as a track external to core vocational training fails to match the sector's

dynamics and leaves the learner without the tools to recognize and exploit the opportunities emerging within a decentralized energy space.

In light of these guidelines, we interpret the modernization of curriculum content not as a quantitative expansion of the list of topics or the introduction of a standalone educational component related to entrepreneurship, but as a restructuring of the internal logic of vocational training content, within which the entrepreneurial aspects of activity are organically integrated into the structure of professional disciplines. This restructuring corresponds to modern approaches to the practice-oriented training of vocational education teachers in renewable energy, which emphasize the need to form a holistic profile of the profession wherein technological, economic, and communicative components do not exist as autonomous modules but are developed within a unified logic of training a specialist capable of independent professional action in the realities of local energy markets (Radkevych, Radkevych & Pryhodii, 2022). Such an approach allows for overcoming the insularity of professional disciplines focused solely on technical operations a feature typical of traditional curricula and opens them up toward the tasks that a technician actually faces in daily entrepreneurial practice.

Deploying the modernized content primarily involves rethinking the mandatory educational components of the professional and theoretical training cycle so that questions of economic feasibility, regulatory compliance, and commercial communication emerge directly within the context of examining technical tasks, rather than being relegated to standalone blocks mastered in isolation from vocational content. While mastering modules dedicated to the installation and commissioning of solar energy systems, heat pumps, and energy storage systems, it is advisable to elaborate not only the technological parameters of the equipment but also its feasibility criteria for various categories of clients: private households, small commercial facilities, condominiums (homeowner associations / OSBB), and public institutions. In doing so, learners master the methodology of comparing equipment options based on cost, payback period, sensitivity to tariff fluctuations, and seasonal factors, justifying their chosen option through the logic of balancing technical and economic indicators. This integration

aligns with the principles of the modular competence-based approach, where the content of an educational module is structured around a real-world task rather than an abstract theoretical concept.

A natural extension of this work is the introduction of legal, economic, and managerial aspects of industry entrepreneurship into educational programs: the structure of the domestic energy market and global trends in renewable energy development, the organizational and legal forms of energy enterprise operations, state support mechanisms for the sector, and the specific functioning of decentralized power supplies and local energy markets at the territorial community level. Special attention should be given to mastering the skills required to conduct facility energy audits, calculate energy demand based on consumption analysis, and select the optimal configuration of an energy system factoring in both technical and economic criteria. It is fundamentally important that these issues be introduced in direct connection with the technical content that learners master in professional disciplines, for only through this logic do the corresponding pieces of knowledge become operational tools rather than mere reference material.

Theoretically, this integration draws upon the classical understanding of entrepreneurial activity as inherently innovative, built upon combining resources and introducing new ways of utilizing them (Bortnyk, 2022), which, in the sectoral context of renewable energy, takes on the character of technological entrepreneurship (tech entrepreneurship) based on transforming scientific and technological knowledge into concrete energy solutions. Directly linked to this is the expansion of content toward understanding the industry's client landscape and the communication practices of an energy entrepreneur: energy projects target a heterogeneous audience of clients, each with specific needs, decision-making criteria, and financing capabilities a private homeowner is primarily guided by the payback period and ease of maintenance, a small commercial facility prioritizes guaranteed uninterrupted power supply, and a local government authority focuses on social impact and the possibility of attracting co-financing. Accordingly, the learner must master the skills of

market segment identification, aligning proposals with client expectations, and justifying the value proposition of a suggested solution within the logic of each named segment. This content-oriented work directly correlates with the need to develop the communicative and managerial-economic competencies emphasized by contemporary research on the professional training of energy specialists (Hrohul & Kobylanskyi, 2026).

By implementing this content update, institutions can revise educational programs while restructuring interdisciplinary links among professional educational components, professional communication modules, and legal training. Theme-based modules built around real-world cases of energy entrepreneurship, digital resources for modeling the economic feasibility of design solutions, and up-to-date analytical materials from industry associations can serve as effective tools in this process. The expected outcome of implementing the first pedagogical condition is the formation of a realistic, holistic, and structured conception among students of the professional activity of a renewable energy system installation and maintenance technician as an activity that inherently incorporates an entrepreneurial dimension from the very beginning, rather than being supplemented by it as an external option. This substantive foundation creates the necessary prerequisite for deploying subsequent pedagogical conditions, each of which requires precisely the kind of sectoral content baseline provided by a modernized educational program.

Alongside the modernization of educational program content, a distinct place within the system of identified pedagogical conditions is occupied by the application of simulation-based learning technologies that model the full cycle of an energy enterprise. The nature of this condition involves creating a controlled practical environment within the educational process. In this environment, the learner sequentially navigates all the key stages of deploying an energy enterprise from identifying market needs and designing a technical solution to conducting a feasibility study (techno-economic justification), selecting a financing model, interacting with clients, and providing post-installation maintenance without the material and financial consequences of potential erroneous

decisions. Its functional purpose within the system is to ensure the transition from the conceptual mastery of industry entrepreneurial practices to the operational refinement of these practices within a context that closely mirrors the actual sector. Without such a simulation stage, the material mastered in the content-oriented phase might remain a mere collection of theoretical information rather than transforming into the capacity for independent action within the realities of local energy markets.

The theoretical foundation for applying simulation technologies to develop entrepreneurial competence is rooted in the tenets of activity theory and experiential learning (experimental learning). According to these frameworks, the deepest acquisition of knowledge and skills occurs through direct activity that approximates real professional circumstances yet remains free from the high cost of failure. Studies focusing on interactive and innovative learning technologies within the vocational education system substantiate the transition from a unidirectional transmission of ready-made knowledge to a subject-subject model (dialogic model). In this model, the educational environment unfolds as a space for the collaborative resolution of real or modeled professional problems (Yermolenko, 2022). In relation to the renewable energy sector, this implies that entrepreneurial skills are formed only through the systematic reproduction of real professional situations in the form of sequential simulation exercises. The particular relevance of the simulation approach for training renewable energy system installation and maintenance technicians stems from the very nature of industry-specific entrepreneurial activity. Real energy projects require the simultaneous consideration of a vast array of diverse factors, which, in actual business practice, involves significant financial risks and is therefore economically unfeasible as a primary instructional tool.

The deployment of simulation technologies within this specified pedagogical condition involves, among other things, the creation of specialized software products and gamified scenarios that model the operations of an energy enterprise under various conditions and situations. Contemporary research has substantiated that simulation modeling, as a method of vocational

education, ensures the formation of a complex of professional competencies, develops analytical, critical, and systems thinking, and enhances learning motivation. Furthermore, the use of digital environments to construct virtual counterparts (digital twins) of physical objects allows for the investigation of complex technological and energy processes without the risk of damaging expensive equipment (Horbatyuk, Rutylo, Zahorodnii, Bureha & Sitkar, 2026). The technical, economic, and commercial dimensions of the simulated energy enterprise model should be integrally represented within a single simulation task; only through this logic does the learner gain experience in decision-making amidst the multi-faceted (multidimensional) reality that characterizes actual entrepreneurial activity in the sector. A natural extension of this work is the construction of interactive scenarios in which students interact with various types of simulated clients, mastering the ability to propose a solution adapted to the specific client's context, justify their technical and commercial recommendations, and align communication terms.

Directly linked to this is the application of gamification elements, such as systems of points, ranks, and competitive formats for the successful management of a virtual energy enterprise. This increases motivation and creates a space for exchanging strategies and comparing the performance of simulated enterprises (Yarych, 2025). The contemporary methodological potential of simulation-based learning is significantly expanded through the use of digital twins of physical energy assets and artificial intelligence tools. These enable the organization of experiments with the operational scenarios of real systems within a safe computing environment and provide an individualized educational trajectory through hybrid learning formats that combine the online processing of analytical materials with classroom work on collaborative design solutions (Hrohul & Kobylanskyi, 2026).

The expected outcome of implementing the second pedagogical condition is the acquisition by learners of comprehensive operational experience in deploying the full cycle of an energy enterprise within a controlled environment. This fosters self-confidence, a readiness to launch independent entrepreneurial activity in the field of renewable

energy, and an understanding of the complex nature of the industry business.

The development of technological mobility and adaptability in learners to dynamic energy market changes through the cultivation of entrepreneurial proactivity constitutes the third pedagogical condition within the defined system. The distinction of its substance lies in forming that personal and activity-based quality manifested in the ability not merely to adjust to rapid technological and market changes, but to actively anticipate them, initiate one's own solutions, and leverage industry dynamics as a source of competitive advantage in entrepreneurial activity. The core of this condition is the purposeful cultivation of a readiness to promptly master new technological solutions, flexibly adapt professional action methods to shifts in the regulatory and market environments, and develop the habit of conducting anticipatory analysis of industry trends and making independent decisions under conditions of uncertainty.

Studies dedicated to personnel management within the enterprises of Ukraine's energy sector emphasize a shortage of qualified specialists and skilled workers, an insufficient alignment of training with market needs, and the necessity of optimizing adaptation programs and implementing lifelong learning (continuous education) as key mechanisms to address these imbalances (Karbovska, Mazur & Bratus, 2024). A specialist confined to the boundaries of formal education and incapable of updating their professional insights objectively loses their competitive standing in the market. In its pedagogical deployment, this condition combines two substantive dimensions formed in organic unity. Technological mobility involves the student mastering the tools for continuous knowledge updates, participating in professional networks, and analyzing the technical specifications of new equipment, which allows them to adapt their own professional approaches to the emergence of new technological solutions in real time. Directly connected to this is entrepreneurial proactivity as an intrinsic personal quality, manifested in the ability to initiate actions that go beyond a mere reaction to external circumstances and to execute one's own system of professional values and goals within the logic of proactive market trend forecasting. Proactivity is formed not spontaneously, but through

the purposeful activation and refinement of the individual personal qualities of the learner, which constitutes the overarching theme of the methodology for developing entrepreneurial competence among future specialists in vocational education institutions. Under such an approach, the primary outcome of the educational process becomes the mastery of algorithms and methods for the independent construction of a trajectory for personal and professional growth (Bazyl, 2021).

The expected outcome of implementing the third pedagogical condition is the formation of a dynamic stance (proactive posture) among learners regarding their own professional development. Within this framework, the renewable energy system installation and maintenance technician views themselves not as a passive executor of industry processes, but as an active agent of their own trajectory amidst continuous technological and market evolution.

The activation of the agentic position (subjective position) of learners through the independent design of entrepreneurial initiatives constitutes the fourth pedagogical condition. The distinction of its content lies in its focus on a qualitative shift in the student's position within the educational process transitioning them from the role of an executor who acquires knowledge and completes externally assigned tasks into the position of an agent (subject) who independently frames problems within the renewable energy sphere, devises their own pathways to resolve them, and accepts responsibility for the consequences of their decisions. The substance of this condition involves the purposeful creation of situations within the educational process wherein the future specialist independently determines which segment of the local energy market interests them, which client needs they plan to satisfy, and how they design their own entrepreneurial initiative.

In the pedagogical dimension, agency (subjectivity) is interpreted as an intrinsic personal quality manifested in the capacity to consciously and responsibly manage the process of one's own professional development, independently formulate strategies for solving professional problems, and critically evaluate the outcomes of one's actions (Bartkiv & Budnik, 2023). The fundamental pedagogical mechanism for implementing this

condition is project-based activity structured around a real-world problem situation, where the learner acts as both the author and executor of their own concept (Chernukha & Vasylieva-Khalatnykova, 2024). Contemporary research on project-oriented learning as a model for forming entrepreneurial competence reveals this mechanism through the integration of motivational-value, cognitive, activity-practical, and reflective components within a single project cycle (Storozhuk, 2026). In training future renewable energy technicians, project-based activity unfolds as the independent development of their own entrepreneurial initiatives, detailing the market segment, target audience, value proposition, feasibility study, and commercial strategy, where the opportunity to engage learners in interaction with real partners is of fundamental importance. The implementation of this condition is accompanied by a meaningful shift in the teacher's role: instead of

occupying the stance of a mentor who sets tasks and evaluates the correctness of their execution, the educator acts as a consultant who helps the learner adequately appraise their own decisions.

The expected outcome of implementing the fourth pedagogical condition is the transition of the future specialist from the position of a passive recipient of ready-made knowledge and skills to the position of an individual who bears personal responsibility for their own professional choices in the field of renewable energy.

In their entirety, the isolated pedagogical conditions form a comprehensive didactic complex within which each condition performs its own specific function, while their inter-component links ensure a collaborative outcome. The generalized functional characteristics of the identified pedagogical conditions are presented in Table 1.

Table 1.

Functional characteristics of pedagogical conditions for the development of entrepreneurial competence in future renewable energy system installation and maintenance technicians

Pedagogical condition	Function within the system	Sphere of manifestation in the educational process	Outcome of implementation
Modernization of the content of educational programs through the integration of contemporary entrepreneurial practices of the energy sector	Foundational content baseline of the system	Content of professional and theoretical training, real-world case studies of energy enterprises, business models of renewable energy generation	A realistic, holistic conception of professional activity as one that inherently incorporates an entrepreneurial dimension from the very beginning
Application of simulation-based learning technologies with modeling of the full cycle of an energy enterprise	Operational refinement of entrepreneurial practices within a controlled environment	Simulation models, gamified scenarios, digital twins, interactive engagements with simulated clients	Comprehensive operational experience in deploying the full cycle of an energy enterprise
Development of technological mobility and adaptability to dynamic energy market changes through the cultivation of entrepreneurial proactivity	Transformation of operational experience into a personal and activity-based quality	Analytical exercises in forecasting industry trends, crisis scenario modeling, culture of experimentation	Readiness for proactive forecasting of industry trends and initiating one's own solutions under conditions of uncertainty

Activation of the agentic position of learners through the independent design of entrepreneurial initiatives	Transitioning the learner into the position of an author of their own decisions	Project-based activity, independent development of entrepreneurial initiatives, interaction with real partners	Personal responsibility of the learner for their own professional choices in the field of renewable energy
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Source: compiled by the author

Conclusions. The current state of the renewable energy sector in Ukraine has created a fundamentally new professional reality for alternative energy generation system installation and maintenance technicians, as energy generation shifts from the level of large-scale energy complexes to the level of territorial communities, small businesses, and individual households. In this market, the technician no longer acts merely as an executor of regulated technical operations within an enterprise, but as an independent economic agent (independent economic entity) for whom entrepreneurial activity is a primary form of self-realization and self-reliance. In this new reality, general entrepreneurial training detached from the industry context fails to provide the readiness that enables a specialist to act independently within the realities of local energy markets. Overcoming this contradiction is possible only if entrepreneurial competence is formed as an industry-driven (sector-specific) component of the future specialist's professionalism.

The pedagogical conditions for developing such competence constitute a purposefully designed didactic complex, the implementation of which fosters the development of learners' readiness for independent professional activity within the realities of local energy markets and accounts for the specifics of entrepreneurial competence formation. The baseline for isolating (identifying) these conditions is a set of processes within the contemporary energy sector (energy generation decentralization, dynamics of technological changes, and the emergence of new market niches for small business) that actualize the need for specific vectors of pedagogical influence. The identified pedagogical conditions are oriented toward the specifics of technological entrepreneurship (tech entrepreneurship) in the field of alternative energy, which distinguishes the proposed didactic approach from traditional entrepreneurial training solutions unlinked to a specific industry context.

A foundational role in this system is occupied by the modernization of educational program content through the integration of contemporary entrepreneurial practices of the energy sector, which introduces real-world case studies of energy enterprises, business models in renewable energy generation, state support mechanisms for the industry, and project financing schemes into mandatory educational components. Drawing upon this substantive foundation, the application of simulation-based learning technologies with modeling of the full cycle of an energy enterprise creates a controlled practical environment within which the learner sequentially navigates the stages of enterprise deployment in the unity of its technical, economic, and commercial dimensions. The development of technological mobility and adaptability to dynamic energy market changes through the cultivation of entrepreneurial proactivity builds upon this operational experience, transforming it into a personal and activity-based quality of proactive forecasting of industry trends and initiating one's own solutions under conditions of uncertainty. The activation of the agentic position (subjective position) through the independent design of entrepreneurial initiatives completes the system's architecture, transitioning the learner from the position of a task executor to the position of an author of their own entrepreneurial decisions who bears personal responsibility for their consequences.

The interdependence of the identified conditions is a fundamental feature of the proposed complex: removing any one of them qualitatively reduces the effectiveness of the entire structure, whereas their simultaneous implementation creates the conditions for transforming the learner from a mere bearer of general notions about entrepreneurial activity into a technician capable of acting as an independent participant in the local energy market. This, in contrast to a mere set of isolated factors, defines the identified pedagogical conditions as an integrated didactic complex.

Implementing the substantiated pedagogical conditions in the practice of vocational education institutions requires updating educational programs and curriculum documentation (instructional planning documentation) in view of the sectoral specifics of alternative energy; integrating real-world cases of industry entrepreneurship and digital tools for modeling the economic feasibility of design solutions into the content of professional and theoretical training; and a qualitative shift in the role of the educator, who transitions from the position of

a mentor to the position of a consultant for the learner's independent professional development.

Further scientific research (scholarly inquiries) may focus on designing a methodology for implementing the identified pedagogical conditions within the educational process of vocational education institutions and its experimental verification across institutions that train specialists for the renewable energy sector.

Conflict of Interest

The author certifies that no conflict of interest (financial, professional, or personal) exists that could have influenced the objectivity of the research results or conclusions. The integrity of the double-blind peer review process was ensured through a mandatory declaration of the absence of conflict of interest submitted via the journal's editorial system. This protocol guaranteed complete author anonymity and the independence of the expert evaluation throughout the entire editorial cycle.

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ПЕДАГОГІЧНІ УМОВИ РОЗВИТКУ ПІДПРИЄМНИЦЬКОЇ КОМПЕТЕНТНОСТІ МАЙБУТНІХ МАЙСТРІВ З МОНТАЖУ ТА ОБСЛУГОВУВАННЯ СИСТЕМ ВІДНОВЛЮВАЛЬНОЇ ЕНЕРГЕТИКИ

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Реферат:

Актуальність. Україна перебуває в активній фазі енергетичного переходу, стратегічну траєкторію якого визначають європейські інтеграційні зобов'язання в рамках Європейського зеленого курсу й національні пріоритети розвитку альтернативної енергетики. Тривалі бойові дії та масовані удари по централізованій енергетичній інфраструктурі надали цьому переходу безальтернативного характеру: розподілена генерація, локальні енергетичні рішення та використання альтернативних джерел енергії в кожній громаді стали умовою енергетичної стійкості держави, а не лише її стратегічним вибором. Нагальна потреба в децентралізації енергопостачання та зростання попиту на встановлення систем альтернативної енергетики з боку домогосподарств, територіальних громад, малого бізнесу й підприємств різної форми власності розширюють зміст професійної діяльності майбутніх майстрів, що дедалі виразніше набуває рис самостійного господарювання в умовах локальних енергетичних ринків. Така трансформація професійних вимог закономірно змінює підходи до підготовки фахівців: підприємницька компетентність із бажаного доповнення до кваліфікації за фахом перетворюється на її обов'язковий галузевий зумовлений складник. Підприємницька компетентність як складова професійної підготовки відображена в чинних освітніх програмах закладів професійної освіти, проте її формування здебільшого реалізується в узагальненому форматі, недостатньою мірою враховуючи специфіку технічних професій загалом і галузевий контекст альтернативної енергетики зокрема: ринкові механізми «зеленої» генерації, регуляторні особливості енергоринку, економіку проектів розподіленої генерації,

спілкування із різними замовниками послуг тощо. Унаслідок цього випускники володіють загальними уявленнями про підприємницьку діяльність, які не трансформуються в готовність діяти в галузевому професійному середовищі. Розв'язання окресленої освітньої проблеми потребує обґрунтування педагогічних умов розвитку підприємницької компетентності майбутнього майстра, взаємопов'язана реалізація яких в освітньому процесі забезпечить формування його як галузево зумовленого складника професійної підготовки, що уможливить самостійну фахову діяльність у конкретних реаліях альтернативної енергетики.

Мета: теоретично обґрунтувати педагогічні умови розвитку підприємницької компетентності майбутніх майстрів з монтажу та обслуговування систем відновлювальної енергетики в процесі здобуття професійної освіти та розкрити характер взаємозв'язків між ними, що складає основу їхньої спільної реалізації в освітньому процесі.

Методи: опрацювання наукового доробку шляхом аналізу та синтезу дало змогу уточнити зміст поняття «педагогічні умови» в контексті розвитку підприємницької компетентності фахівців з альтернативної енергетики й виявити недостатньо досліджені аспекти проблеми; системний підхід забезпечив розгляд педагогічних умов як цілісного дидактичного комплексу, у межах якого кожна умова перебуває у функціональних зв'язках з іншими; методи узагальнення й конкретизації застосовано для переходу від концептуальних положень до операційних характеристик визначених умов; пріоритетність педагогічних умов визначено за результатами експертного оцінювання й ранжування.

Результати: уточнено зміст поняття «педагогічні умови розвитку підприємницької компетентності» стосовно галузевого контексту альтернативної енергетики, що дало змогу конкретизувати його для професій, пов'язаних з альтернативною енергетикою; теоретично обґрунтовано педагогічні умови, орієнтовані на формування підприємницької компетентності майбутнього фахівця відповідно до реалій локальних енергетичних ринків і динамічних змін у визначеній галузі економіки; розкрито міжкомпонентні взаємозв'язки між педагогічними умовами, що зумовлюють їхнє взаємопідсилення в освітньому процесі й визначають їхню одночасну реалізацію як передумову результативного розвитку підприємницької компетентності майбутнього майстра з монтажу систем відновлювальної енергетики.

Висновок: теоретично обґрунтовані педагогічні умови розвитку підприємницької компетентності майбутніх майстрів з монтажу та обслуговування систем відновлювальної енергетики ґрунтуються на розумінні цієї компетентності як галузево зумовленого утворення, зміст і способи формування якого визначаються специфікою професійної діяльності у сфері альтернативної енергетики. Визначені педагогічні умови охоплюють ключові складові освітнього процесу й у їхній сукупності забезпечують перехід здобувачів освіти від ознайомлення з основами підприємництва до самостійної підприємницької діяльності в реальному галузевому середовищі. Обґрунтовані умови є взаємозалежними: їхня результативність досягається лише за умови одночасної реалізації, що визначає їх як цілісний дидактичний комплекс, а не сукупність незалежних чинників. Отримані результати створюють підґрунтя для оновлення освітніх програм і навчально-плануючої документації щодо підготовки майстрів з монтажу систем відновлювальної енергетики в закладах професійної освіти, розроблення методичних рекомендацій для педагогічних працівників закладів і подальшого проектування методики розвитку підприємницької компетентності означених фахівців.

Ключові слова: професійна освіта, педагогічна умова, заклад професійної освіти, компетентнісний підхід, підприємницька компетентність, альтернативна енергетика, галузева зумовленість, підприємницька проактивність, технологічна мобільність, суб'єктна позиція, проектна діяльність.

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