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INTENSIFICATION OF VOCATIONAL TRAINING FOR LEARNERS VIA SMART TECHNOLOGIES

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Abstract

Relevance: The contemporary global educational architecture is undergoing a radical shift toward "Vocational Education 4.0," driven by the requirements of Industry 4.0 and systemic digital transformation. In Ukraine, this process is critically compounded by martial law, energy instability, and the urgent need for economic resilience, which necessitate innovative tools to ensure instructional continuity. Traditional pedagogical methods often struggle to maintain instructional pace and quality amidst these high-stress environments. A significant research gap exists regarding the systemic integration of SMART complexes, not as peripheral aids, but as primary instruments for the intensification of training. Addressing this gap is vital for aligning national vocational standards with the European educational space while compensating for physical infrastructure limitations.

Purpose: This study aims to theoretically substantiate and empirically evaluate the potential of AI-enhanced SMART technologies as strategic tools for intensifying vocational training. The objective is to develop a conceptual model that optimizes learning efficiency and professional competence development amidst digital challenges and security risks.

Methods: The research followed a phased mixed-methods design, integrating theoretical analysis with large-scale empirical investigation. Initially, an epistemological analysis of SMART education and Industry 4.0 literature was conducted to identify key theoretical pillars. The empirical stage involved a nationwide survey of 4,645 vocational educators across all macro-regions of Ukraine, ensuring high territorial and expert representativeness – with over 73% of participants possessing ten or more years of professional experience. Data analysis focused on the efficacy of digital tools under martial law, the dominant forms of learning organization, and technological barriers. Finally, structural-logical modelling was employed to synthesise these findings into a four-block conceptual framework, integrating adaptive algorithms and predictive learning analytics to ensure instructional precision and reproducibility.

Results: Empirical findings reveal that SMART complexes serve a critical stabilising function, with 86.1% of educators reporting a significant or moderate acceleration in knowledge and skill acquisition. Furthermore, 67.3% of respondents evaluated these technologies as highly effective for maintaining educational continuity under martial law conditions. Intensification is achieved through immediate feedback loops, the automation of routine assessments, and the personalization of learning trajectories. The study proposes a comprehensive four-block conceptual model: 1) a techno-adaptive infrastructure utilizing VR/AR and adaptive modules; 2) an analytical-predictive block that monitors the "digital footprint" of learners; 3) a personalized support system powered by generative AI and intelligent tutors; and 4) a result-competency output aligned with labour market demands. While 75.8% of participants acknowledge the positive impact of AI on educational quality, significant systemic barriers – specifically unstable connectivity, energy disruptions, and varying levels of digital fluency among staff – remain primary challenges to full-scale implementation.

Conclusions: The study concludes that intensifying vocational training via SMART technologies represents a systemic educational evolution rather than a mere technological upgrade. The proposed model facilitates a transition toward "anticipatory training," transforming the educator's role from a transmitter of knowledge into a designer of educational experiences. Effective implementation requires a dual-track strategy: upgrading institutional digital infrastructure and fostering strategic digital self-regulation among learners. Theoretically, this research bridges the gap between adaptive learning theories and vocational didactics. Practically, the results provide a scalable blueprint for modernising VET systems in crisis-affected regions, establishing new standards for resilient and technologically advanced human capital development.

Keywords: *resilience, Industry 4.0, AI-driven learning, instructional design, digital fluency, adaptive pedagogy, educational ecology.*

Introduction. Under contemporary socio-economic and security conditions, the intensification of vocational training for learners acquires strategic importance for ensuring the competitiveness of specialists and the resilience of the national economy. For Ukraine, this issue is particularly pertinent within the context of martial law, the digital transformation of society, and European integration processes. Under such circumstances, vocational education requires tools capable of enhancing instructional efficiency without compromising quality or practical orientation.

The implementation of SMART complexes featuring Artificial Intelligence (AI) elements in vocational education institutions creates the prerequisites for a qualitative renewal of the educational process. Studies (Dovhopolyk & Smyrnova, 2021) demonstrate that the integration of SMART technologies facilitates the optimisation of learning activities, the automation of results monitoring, and the improvement of learners' achievement levels. During periods of distance or blended learning–which became a mass phenomenon due to wartime challenges – digital solutions enable the compensation for limited access to physical facilities and ensure the continuity of professional training (Eurydice, 2024).

The "Vocational Education 4.0" concept entails the transformation of the learning environment into a high-tech interactive system that integrates digital platforms, cloud services, and learning data analytics. In this context, SMART technologies serve as an instrument of intensification through the implementation of adaptive learning, where AI algorithms adjust content complexity according to the individual progress of the learner (Patiño et al., 2023; Spector et al., 2024).

The intensification of vocational training via SMART technologies is realised through: accelerated feedback, which shortens the "task–assessment–correction" cycle and increases learning productivity (Mwilongo & Mwita, 2025); the personalisation of the educational trajectory, which allows for the adaptation of pace and content to the individual needs of the learner (Pryhodii & Radkevych, 2025); and cognitive stimulation and gamification, which enhance motivation and facilitate deeper internalisation of occupational competencies (Deterding et al., 2011).

Simultaneously, the digital transformation of vocational education is accompanied by several challenges: the need to enhance the digital competence of vocational educators (Caena & Redecker, 2019; Tondeur et al., 2017), the updating of the regulatory and methodological framework (Bazeliuk, 2021), the assurance of cybersecurity (Zwilling et al., 2022), and equitable access to technological resources (Romero et al., 2025). Nevertheless, international research indicates that the systemic implementation of AI and digital tools creates conditions for cultivating a new generation of specialists capable of operating effectively within Industry 4.0 (Haleem et al., 2022).

Modern adaptive vocational training systems allow for the integration of theoretical content with virtual simulations of industrial processes, thereby aligning instruction with authentic professional situations (Long et al., 2025). Such an approach corresponds to Ukraine's digital transformation strategy and promotes the harmonisation of the national vocational education system with the European Education Area (Kulynych, 2021).

Consequently, the intensification of vocational training through SMART technologies represents not only a technological innovation but also a systemic factor in the modernisation of vocational education. The relevance of this study is driven by the necessity to provide a scientific substantiation of the methodological foundations for using SMART tools to enhance the efficiency of learner preparation amidst digital and security challenges.

In contemporary scholarly discourse, SMART education is viewed as an evolutionary stage in the development of digital learning, combining technological innovation, adaptive methodologies, and educational data analytics. In a broad sense, SMART education is the process of acquiring and refining knowledge, skills, values, and professional attitudes based on the integration of digital technologies with modern pedagogical approaches. The SMART acronym (Specific, Measurable, Achievable, Relevant, Time-bound) emphasises the orientation of the educational process toward clearly defined, measurable, and attainable outcomes, ensuring its efficiency and manageability (Bjerke & Renger, 2017).

Within the context of vocational education, the SMART paradigm transforms traditional teaching models into dynamic, technology-enriched educational ecosystems capable of responding to labor market needs and individual learner trajectories. Thus, SMART education merges the competency-based approach with digital personalisation, meeting the requirements of Industry 4.0.

One of the defining characteristics of SMART education is its technological multi-component nature. Researchers highlight the integration of AI as a tool for automating assessment, predicting learning outcomes, and adaptive content management (Tusquellas et al., 2024). Augmented (AR) and Virtual Reality (VR) technologies expand the possibilities for modelling professional situations and creating simulated industrial environments (Wolf et al., 2022), while the Internet of Things (IoT) ensures the integration of physical and digital components of the learning space (Mehar et al., 2024).

The application of personalised learning platforms enables real-time educational data analytics, automatically adapting the content and complexity of tasks according to the individual progress of the learner (Bhutoria, 2022). In this context, SMART education functions as a data-driven system where managerial and pedagogical decisions are based on evidence-based indicators of learning effectiveness. Digital collaboration tools integrated into the SMART environment facilitate the development of communication and teamwork competencies, which are critical for the modern professional environment. Consequently, the technological component of SMART education ensures not only the intensification of knowledge acquisition but also the cultivation of meta-competencies.

A vital feature of the SMART approach is its orientation toward the systematic collection and analysis of learning data. Educational platforms accumulate information regarding achievement dynamics, typical errors, and the cognitive characteristics of learners, which allows for the adjustment of educational strategies based on empirical evidence (Krishnan et al., 2022). This approach enhances the transparency and manageability of the educational process, contributing to its overall effectiveness.

SMART education is regarded as a tool for expanding access to quality education. The use of digital resources and cloud services creates conditions for the instruction of individuals with special educational needs and learners from remote regions (Akhbash & Kugai, 2022). Thus, the SMART paradigm combines innovation with the principles of inclusivity and social justice.

The cultivation of critical thinking, digital literacy, and the capacity for continuous professional development is identified as one of the key outcomes of SMART education (Yasa et al., 2024). Professionally oriented digital tools that model real industrial scenarios facilitate the preparation of the workforce for global challenges (Itransition, 2024).

Within the structure of vocational education, the SMART complex of a curriculum subject occupies a distinct position, defined as an integrated system of regulatory, methodological, and digital resources operating within the institution's information-educational environment and aimed at achieving programmed learning outcomes (Pryhodii, 2019).

One of the primary advantages of SMART complexes is their adaptivity. The use of machine learning algorithms allows for the assessment of learner preparation levels and the automatic adjustment of the complexity and sequence of instructional tasks. This approach ensures the personalisation of the educational process and enhances the efficiency of developing professional readiness (Radkevych, 2023).

The integration of theoretical content with practical modules–such as virtual laboratories, simulators, and industry-specific projects–enables the modelling of professional situations that closely mirror the real production environment (Potkonjak et al., 2016). This reduces the transition period for graduates entering the workforce and narrows the gap between the educational and professional environments.

The use of learning data analytics provides continuous monitoring of learner progress and the delivery of rapid feedback. The early detection of knowledge gaps allows for the timely correction of the educational trajectory, which facilitates the optimisation of learning pace and increases productivity (Sacristán et al., 2009).

Despite a significant body of research dedicated to digital technologies in education, scholarly literature reveals a fragmentation of approaches regarding the systemic substantiation of SMART complexes specifically as an instrument for intensifying vocational training under crisis and wartime challenges. Most works focus on isolated technological solutions, whereas the comprehensive impact of SMART technologies on the speed, quality, and sustainability of competency development requires further empirical confirmation.

Thus, the synthesis of scientific sources allows for the conclusion that SMART education forms the theoretical and methodological foundation for the intensification of vocational training; however, the task of developing integrated models for implementing SMART technologies remains relevant, taking into account digital, organisational, and ethical aspects of their operation.

Purpose of the study: Scholarly discourse extensively examines the potential of SMART technologies and artificial intelligence to enhance instructional effectiveness; however, the systemic integration of these tools within the vocational education framework – specifically regarding the intensification of training and the cultivation of professional competencies – remains insufficiently explored. The study aims to provide a theoretical and methodological substantiation, alongside an empirical analysis, of the potential of SMART technologies enhanced by artificial intelligence algorithms as a strategic instrument for intensifying the vocational training of learners amidst digital and security challenges.

Methods: The study follows a phased mixed-methods research design, integrating theoretical-analytical and empirical components with subsequent conceptual modelling. During the first stage, a systemic analysis of scholarly sources regarding the phenomenon of SMART education, SMART technologies, and SMART complexes as instruments for intensifying vocational training was conducted; this process enabled the delineation of theoretical foundations and the identification of existing research gaps. In the second stage, a survey of vocational educators was carried out to ascertain their readiness to utilise SMART technologies, evaluate the potential for instructional intensification, and identify organisational and technological barriers to implementation. The synthesis of quantitative and qualitative data analysis results formed the basis for the third stage: the development of a conceptual model for intensifying vocational training via SMART technologies. The proposed model is oriented toward future implementation within the vocational education system and entails the integration of adaptive digital tools, educational data analytics, and personalised learner support within systemic and competency-based frameworks.

A total of 4,645 vocational educators from educational institutions across Ukraine participated in the study (Radkevych et al., 2025). The sample encompasses representatives from various regions of the state, ensuring appropriate territorial representativeness and permitting the interpretation of results within a national context. A significant proportion of respondents possesses extensive professional experience, which enhances the expert value of the gathered responses.

Analysis of teaching experience revealed a predominance of seasoned professionals, as over two-thirds of the participants have worked in the education sector for more than 10 years. Simultaneously, the sample includes early-career educators with up to 5 years of experience (18.32%), allowing for the consideration of diverse professional perspectives (Table 1).

Table 1.

Distribution of respondents by length of teaching experience

Teaching Experience	Number (n)	Percentage (%)
Less than 1 year	300	6.46%
1–3 years	315	6.78%
3–5 years	236	5.08%
5–10 years	393	8.46%
Over 10 years	3401	73.22%
Total	**4645**	**100%**

The geographic scope of the study is extensive and includes all macro-regions of Ukraine. While the largest number of respondents represents the Western and Central regions, the sample also features significant representation from the Eastern and Southern provinces, which operate under heightened security challenges (Table 2).

Table 2.

Distribution of respondents by region of educational institution location

Region of Ukraine	Number (n)	Percentage (%)
Western	1462	31.48%
Central	1342	28.89%
Eastern	936	20.15%
Southern	662	14.25%
Northern	243	5.23%
Total	**4645**	**100%**

Consequently, the sample is characterised by a high level of professional experience among participants and broad regional representation, ensuring the reliability and generalisability of the research findings.

The adoption of a mixed-methods approach is necessitated by the complexity of the digital transformation within VET. Quantitative data provided a macro-level overview of technological adoption rates, whereas qualitative insights from vocational instructors highlighted the nuanced pedagogical shifts required to move from traditional to SMART-enhanced instruction. By utilising a systemic approach, the researchers were able to treat the vocational training process not as a static set of curricula, but as a dynamic ecosystem.

The "intensification" aspect of this model refers specifically to the acceleration of the learning cycle. In traditional VET settings, the lag between theory and work-based learning (WBL) can result in skill decay. SMART technologies, particularly those involving AI-driven simulations, bridge this gap by providing immediate feedback loops. The high concentration of experienced educators (73.22% with over 10 years of experience) is significant; it indicates that the drive for SMART integration is not merely a trend adopted by "digital natives" but is recognised as a necessity by the established workforce.

Furthermore, the regional distribution accounts for the socio-political realities of Ukraine in 2026. The inclusion of the Eastern and Southern regions (34.4% combined) ensures that the conceptual model remains robust even in environments where physical infrastructure may be compromised, emphasizing the role of cloud-based SMART complexes in maintaining educational continuity.

Result & discussion: An analysis of the empirical research findings identifies key patterns regarding the impact of SMART technologies on the intensification of vocational training under martial law. The survey encompassed members of the teaching community across various regions of Ukraine (notably Central, Western, and Southern), ensuring the representativeness of data concerning the current state of digitalization in Vocational Education and Training (VET).

Among those surveyed, 46.5% indicated that the face-to-face (traditional) form of learning dominates in their institutions, 38.3% reported blended learning, and 15.2% identified distance learning. Simultaneously, an assessment of the chosen format's effectiveness in ensuring a personalized learning pace revealed positive dynamics: 1,777 respondents defined it as "very effective," while 2,213 deemed it "moderately effective." Collectively, this constitutes over 85% positive ratings. Only 244 individuals (approximately 5%) consider the format to be of low effectiveness or entirely ineffective (Figure 1).

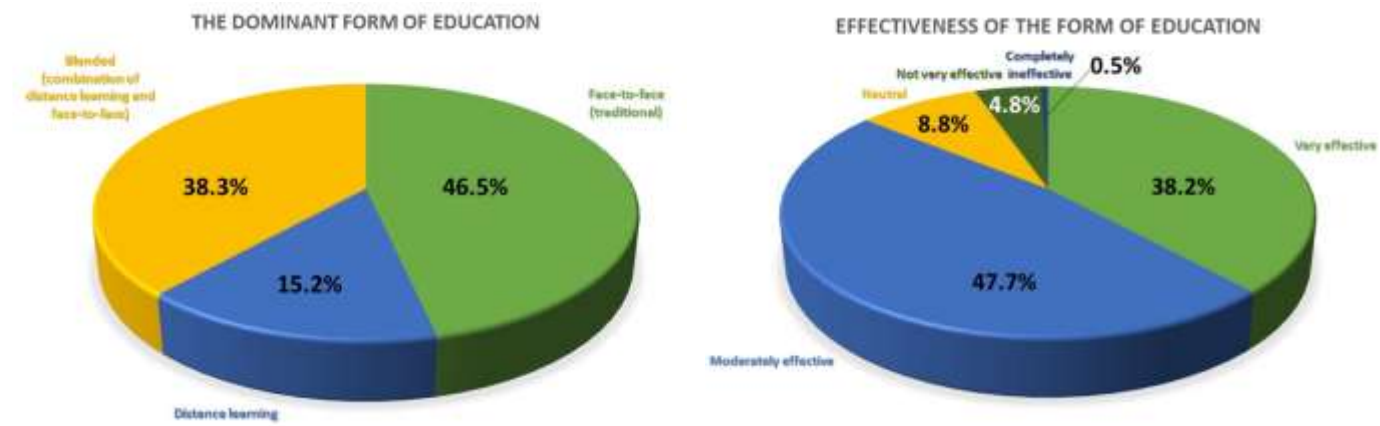

Figure 1. Distribution of forms of learning organisation and assessment of their effectiveness for personalised training pace

Hence, regardless of the organizational model (face-to-face, blended, or distance), vocational educators demonstrate a high readiness to integrate digital tools to support the individualization of learners' educational trajectories. The blended format serves as the most conducive environment for implementing SMART complexes, as it combines synchronous and asynchronous interaction.

SMART complexes are applied regularly by 33.8% of teaching staff, while a further 45.6% use them occasionally depending on the subject matter, technical conditions, and educational objectives. Consequently, nearly 80% of respondents already possess practical experience in integrating SMART solutions into the educational process, suggesting their gradual consolidation within daily pedagogical practice. Furthermore, 13.8% of those surveyed noted that they do not yet use such tools but plan to implement them in the near future, demonstrating positive dynamics in readiness for digital change. Conversely, 6.9% are either unfamiliar with the concept of SMART technologies or do not plan to apply them, which may be attributed to infrastructural constraints or insufficient digital competence.

The results obtained indicate a sufficiently high level of digital transformation within the educational environment. SMART complexes are gradually ceasing to be perceived as innovative novelties and are transitioning into the category of standard instrumentation for modern pedagogical activity, providing flexibility, interactivity, and the intensification of vocational training.

Specifically, 2,421 respondents defined SMART complexes as "effective," and 704 as "very effective" for organizing learning under martial law. Collectively, this represents 67.3% positive evaluations, indicating a predominantly high level of trust among vocational educators in digital solutions during crisis situations. Another 27.6% of respondents consider them partially effective, emphasizing that efficacy depends on technical conditions, the preparedness level of learners, and the stability of the internet connection. Only about 5% of respondents noted low or a complete lack of effectiveness, which constitutes a relatively insignificant proportion and does not substantially affect the overall positive trend (Figure 2).

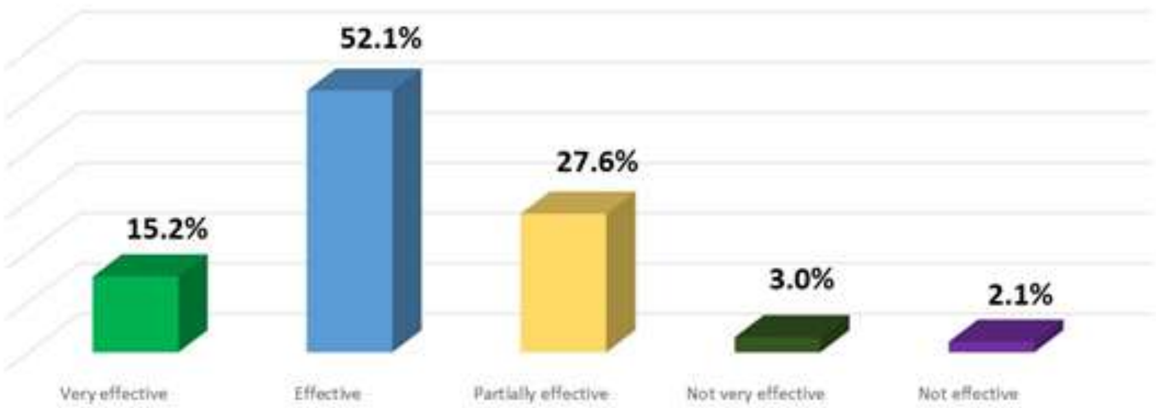

Figure 2. SMART complexes efficiency

The gathered data convincingly confirm that SMART complexes perform a compensatory and stabilizing function in crisis conditions, ensuring the continuity of the educational process even amidst restrictions on physical presence, the displacement of participants, or infrastructure damage. Tools for asynchronous learning, automated assessment, cloud-based storage of instructional content, and the use of adaptive modules–which allow for the maintenance of an individual learning pace–acquire particular relevance. Thus, SMART complexes serve as a vital instrument for ensuring the resilience of vocational education in unstable environments.

The most revealing block within the structure of the results pertains directly to the intensification of the educational process. This specific aspect allows for an assessment of the actual impact of SMART technologies on the dynamics of developing professional competencies in learners. According to the survey results, 2,720 vocational educators noted that using SMART complexes "moderately accelerates" the pace of knowledge acquisition, while 1,280 respondents believe they "significantly accelerate" learning. Combined, this represents 86.1% positive ratings, which is an extremely significant indicator for confirming the effectiveness of digital educational solutions. Only 3.5% of those surveyed expressed the opinion that the application of SMART technologies slows down the learning process, while a negligible proportion of respondents noted no significant changes. Thus, the empirical data support the research hypothesis regarding the intensification potential of SMART complexes. This acceleration is achieved through interactivity, instant feedback, automated monitoring, and the capacity for pace individualization (Figure 3).

The survey results allow for the conclusion that SMART complexes are perceived by vocational educators as a multidimensional tool for modernizing professional training. In the open-ended response section, the following advantages were most frequently recorded: interactivity of instructional materials, flexibility in educational organization, automated knowledge assessment, individualization of learning pace, and increased learner motivation. Respondents typically cited these characteristics in combination, indicating a holistic perception of SMART complexes as an integrated digital environment.

Notably, 81.6% of teaching staff define SMART complexes as "rather useful" or "very useful" for training specialists in accordance with labor market needs. This level of support demonstrates an awareness of the link between the digitalization of the educational process and the development of competitive professional competencies. Furthermore, 2,548 respondents rated the flexibility of adapting SMART complexes to individual needs as moderate, while 998 rated it as high. Collectively, this constitutes over 76% positive ratings of the system's adaptive potential, confirming its ability to provide personalized educational trajectories.

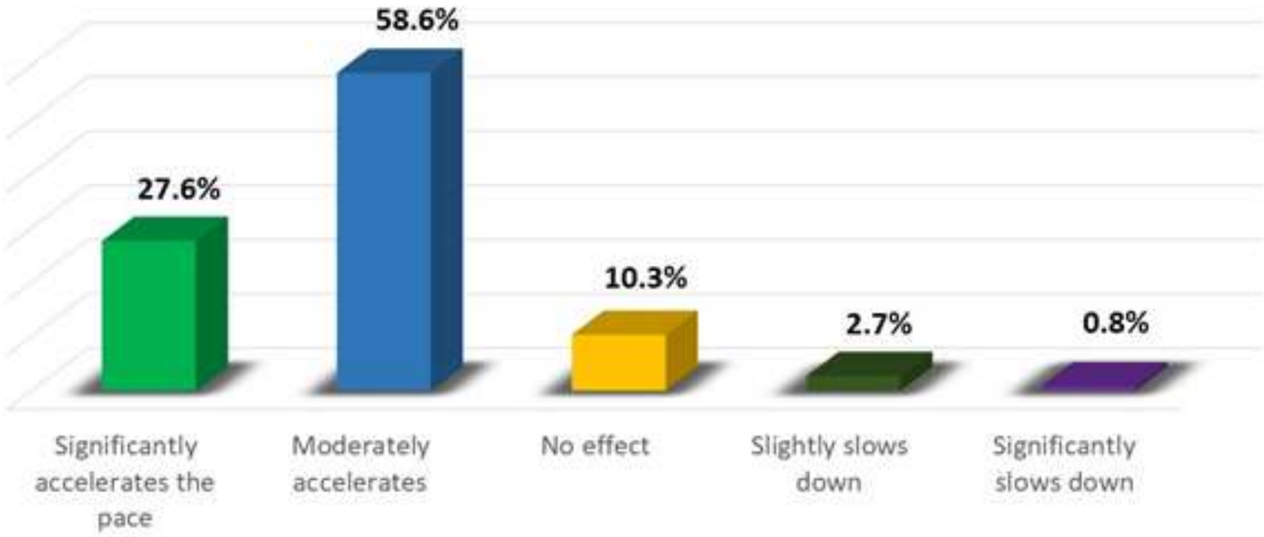

Figure 3. Impact on the rate of knowledge and skill acquisition

Under crisis conditions, digital tools play a stabilizing role. Specifically, 2,428 individuals noted that SMART complexes partially ensure learning continuity during power outages or air raid alerts, while another 960 stated they provide full continuity. Thus, 3,388 respondents recognize their substantial contribution to maintaining educational resilience, confirming the function of digital technologies as a tool for compensatory learning organization. Simultaneously, the study identified systemic barriers to implementation. The most common challenge involves technical issues: 1,924 respondents pointed to unstable internet connections and power supply disruptions. Additional factors identified include the insufficient digital literacy of learners and the need for further professional development of teaching staff. Financial costs for creating and maintaining the SMART environment infrastructure remain a significant limitation. Consequently, most obstacles are infrastructural or personnel-related, requiring strategic support for digital modernization at the management decision level.

The role of artificial intelligence elements warrants separate mention: 75.8% of respondents believe that their integration moderately or significantly enhances the quality of the educational process. This indicates a positive perception of learning data analytics, adaptive algorithms, and automated pedagogical decision-support systems. Collectively, these digital indicators confirm the gradual transition of educational institutions toward the "Vocational Education 4.0" model, within which SMART complexes serve as the instrumental foundation for the systemic transformation of vocational training.

The proposed conceptual model for the intensification of vocational training is based on the synergy of systemic and competency-based approaches, where SMART technologies act not merely as tools but as an environment for fostering professional mastery. The systemic approach treats the training process as an integrated structure, where changes in one element (e.g., the implementation of AI analytics) lead to the transformation of the entire system. The competency-based approach defines the ultimate goal–the development of not only knowledge but also the ability to apply it flexibly in unstable technological conditions.

Within this model, intensification is understood not as an increase in information volume, but as an enhancement of the efficiency of each instructional time unit through:

- the use of adaptive algorithms;
- the minimization of reproductive labor via the automation of routine tasks;
- the provision of instantaneous feedback.

The proposed model includes four interconnected blocks (Figure 4):

1. **Technological-Adaptive Block (SMART Instrumentation).** The central element is the SMART complex–an interactive

environment that accumulates multimedia content, VR/AR simulators, and training equipment. Unlike traditional electronic courses, the SMART complex possesses the property of self-organization: it adjusts task complexity to the learner's level, which is supported by survey results (most educators note a "significant acceleration of the learning pace" when using such means).

2. **Analytical-Predictive Block (Learning Analytics).** The model entails the integration of tools for collecting and analyzing educational data (Big Data in education). This allows the instructor to monitor the "digital footprint" of each learner: time spent on a topic, typical errors, and activity peaks. Analytics enable a shift from merely recording results (exams) to preventive intervention–identifying at-risk groups during the theory acquisition stage.
3. **Personalized Support Block.** The integration of artificial intelligence elements (Generative AI, chatbots) provides 24/7 support. Within the model, AI acts as a tutor, helping the learner bridge knowledge gaps, which is particularly critical in distance learning and unstable power supply conditions when direct contact with the instructor may be limited.
4. **Result-Competency Block.** The final outcome is the developed digital and professional competence that meets labor market demands. The model is oriented toward "anticipatory learning," where the learner masters skills for working with technologies that are only beginning to be implemented in industry.

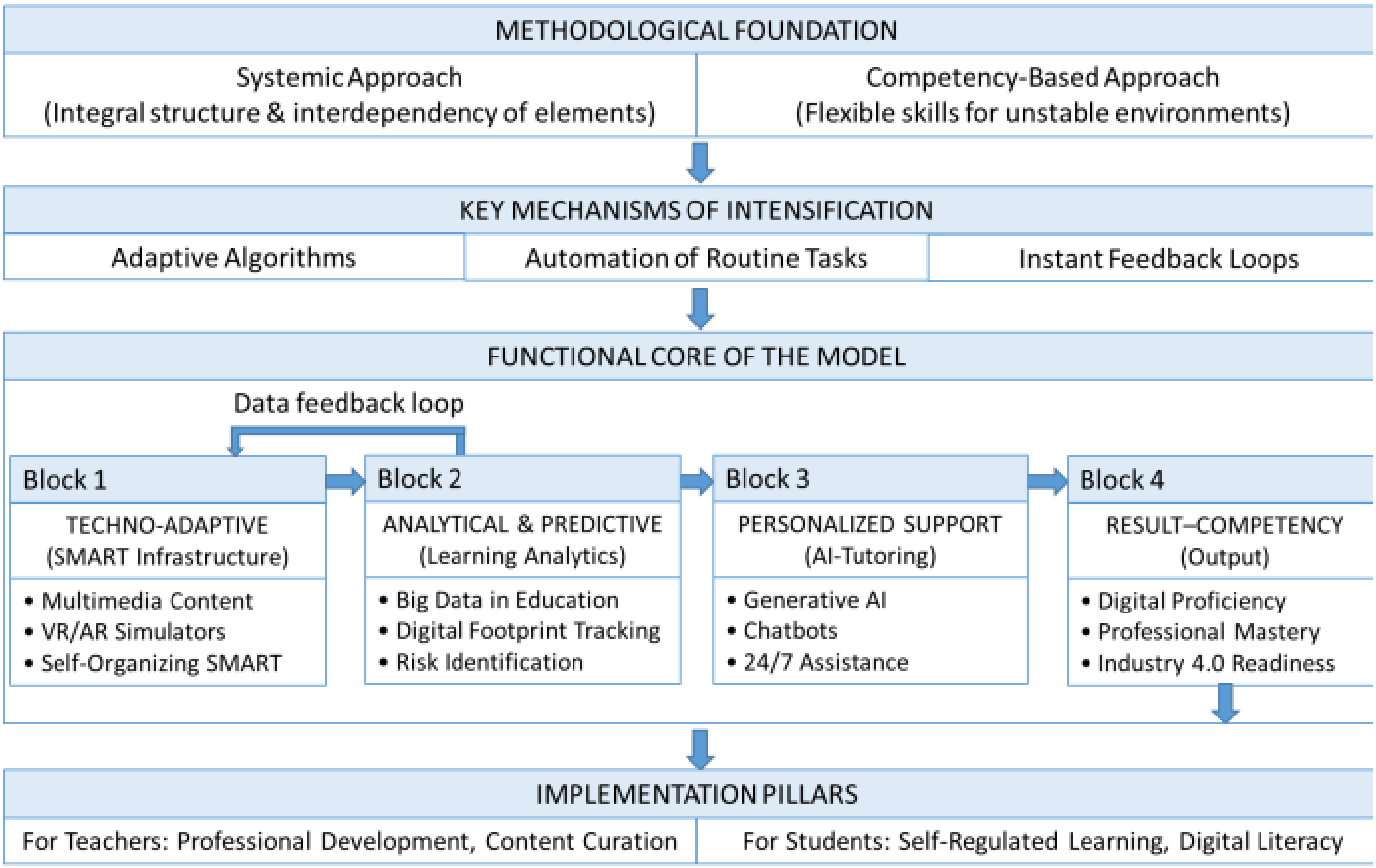

Figure 4. Conceptual Model of vocational training intensification via SMART technologies

Successful implementation of the model requires overcoming the barriers identified during the survey: low digital literacy and technical constraints. The conceptual model envisages two-level training:

- **For vocational educators:** development of professional development programmers with an emphasis on content curation rather than simple reproduction;
- **For learners:** development of self-learning skills within a digital environment.

The model features a modular architecture, allowing for scalability: from an individual educational institution to the national level through the creation of unified SMART platforms for vocational education. This will allow for the unification of quality requirements for training while maintaining the flexibility of regional components.

The scientific novelty of the proposed model lies in the comprehensive combination of adaptive learning with predictive analytics within the specific conditions of vocational education. The substantiated intensification model serves as a response to Industry 4.0 challenges. It transforms the role of the instructor from a "transmitter of knowledge" to a "designer of educational experiences," and the learner from a passive listener to an active user of intelligent systems.

An analysis of the educators' responses confirms that the use of SMART technologies significantly or moderately accelerates the pace of knowledge acquisition. This confirms a key principle of the Education 4.0 concept–learning personalization. Research indicates that adaptive digital environments allow learners to become "architects of their own learning," which is especially important for vocational education where group heterogeneity requires an individual approach (Thomann, 2025).

Most respondents rated SMART complexes as "effective" or "very effective" even under martial law. However, the survey results revealed a serious problem: technical challenges (internet, power supply) remain the primary barrier to continuous learning. In scholarly literature, this phenomenon is described as Emergency Remote Teaching (ERT). Studies of education in crisis conditions show that although digital tools ensure educational continuity, they cannot fully replace the face-to-face environment amidst constant destructive factors (Moore & Hodges, 2023; Bakhov et al., 2021).

The surveyed instructors predominantly evaluate the impact of AI on the quality of the educational process positively or neutrally. This correlates with the global trend of using Generative AI to automate routine tasks, such as assessment. The use of AI in vocational education allows for the improvement of learners' technical and technological competence, which is critical for Industry 4.0 requirements (World Economic Forum, 2024; Wahjusaputri et al., 2024; Costa Júnior et al., 2025).

According to the survey, instructors view SMART complexes as a tool for developing "soft skills" and a multidisciplinary approach. This corresponds to the requirements of the modern economy, where critical thinking, adaptability, and the capacity for lifelong learning are valued. The integration of Industry 4.0 technologies into the educational process of VET institutions creates a "bridge" between academic knowledge and the practical skills required in the workplace (González-Pérez & Ramírez-Montoya, 2022; Pinto & Reis, 2023; Moraes et al., 2023).

Despite the high utility of SMART technologies, instructors point to a "lack of training among educators" and "low digital literacy among students." These results confirm findings that successful digital transformation requires not only equipment but also the systemic development of Digital Fluency among all participants in the educational process (Garzón et al., 2025).

The data obtained demonstrate that the application of SMART technologies in Ukrainian VET institutions is strategically important for implementing the "Vocational Education 4.0" concept. However, the effectiveness of these tools is significantly limited by external factors (war, energy crisis) and internal deficits (digital skills). To achieve sustainable results, it is necessary to combine technological innovations with the targeted preparation of teaching staff to work in conditions of digitalization and the application of artificial intelligence.

Conclusions. The conceptual model of vocational training intensification via SMART technologies proposed in this study demonstrates that digital transformation in education should not be reduced to the mere implementation of technological tools. Instead, it requires a systemic reconfiguration of pedagogical logic, institutional infrastructure, and stakeholder roles. The findings confirm that intensification is achieved not by increasing instructional load, but by optimizing cognitive, organizational, and technological processes within an integrated digital ecosystem. The developed hierarchical model highlights the interdependence between methodological foundations, functional technological blocks, and implementation conditions. The systemic approach ensures the structural coherence of all components, while the competency-based approach aligns learning outcomes with the dynamic demands of Industry 4.0. Their integration enables a shift from content transmission to competence construction, where adaptability, digital literacy, and professional flexibility become dominant educational priorities. A key contribution of the study lies in structuring intensification mechanisms into operational domains: adaptive algorithms, automation of routine processes, and instant feedback loops. These mechanisms reduce temporal losses, personalize learning trajectories, and increase instructional precision. Importantly, intensification is conceptualized not as acceleration, but as qualitative optimization supported by data-driven decision-making and predictive analytics.

The functional architecture of the model–comprising techno-adaptive infrastructure, analytical-predictive systems, AI-powered personalized support, and result-competency output–forms a closed-loop ecosystem. Learning analytics serve not only monitoring purposes but also adaptive regulation, feeding data back into the SMART infrastructure to modify learning scenarios dynamically. This feedback cycle transforms the educational environment into a self-adjusting system capable of responding to learner needs in real time. The integration of AI-based tutoring tools further enhances the accessibility and continuity of professional education. Continuous support mechanisms, including generative AI and intelligent chat systems, extend the temporal and spatial boundaries of vocational learning. As a result, learners are empowered to develop self-regulated learning behaviours while maintaining guided progression through complex professional content. At the outcome level, the model contributes to the development of market-ready competencies aligned with Industry 4.0 requirements. The transition from knowledge accumulation to adaptive expertise fosters not only digital proficiency but also strategic thinking, problem-solving capacity, and readiness for technological uncertainty. In this sense, vocational training becomes anticipatory rather than reactive.

Equally significant are the implementation pillars identified in the study. The intensification process remains sustainable only when vocational educators possess instructional design competencies and the ability to curate digital content strategically. Simultaneously, learners must develop digital self-regulation and responsible engagement within intelligent learning environments. Thus, technological modernization must be accompanied by human capacity development. Overall, the proposed model provides a scalable framework applicable across vocational and technical education systems undergoing digital transformation. It bridges pedagogical theory and technological practice, offering a structured pathway toward sustainable intensification. Future research may focus on empirical validation across different institutional contexts and on the quantitative measurement of learning efficiency gains achieved through SMART-based integration. Vocational training intensification via SMART technologies represents not a technological upgrade, but a systemic educational evolution. Its effectiveness depends on coherent methodological grounding, adaptive digital infrastructure, data-informed governance, and the synchronized development of both vocational educators and learners within an intelligent educational ecosystem.

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ІНТЕНСИФІКАЦІЯ ПРОФЕСІЙНОЇ ПІДГОТОВКИ ЗДОБУВАЧІВ ОСВІТИ ЗАСОБАМИ SMART-ТЕХНОЛОГІЙ

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Реферат:

Актуальність. Сучасна глобальна освітня архітектура зазнає радикальних змін у напрямі «Професійної освіти 4.0», що зумовлено вимогами Індустрії 4.0 та системною цифровою трансформацією. В Україні цей процес критично ускладнюється умовами воєнного стану, енергетичною нестабільністю та нагальною потребою в економічній стійкості, що вимагає впровадження інноваційних інструментів для забезпечення безперервності навчання. Традиційні педагогічні методи часто неспроможні підтримувати належний темп та якість викладання в умовах такого високого навантаження. Існує значна наукова прогалина щодо системної інтеграції SMART-комплексів не як периферійних засобів, а як основних інструментів інтенсифікації підготовки. Подолання цієї прогалини є життєво важливим для гармонізації національних професійних стандартів із європейським освітнім простором та компенсації обмеженості фізичної інфраструктури.

Мета: Це дослідження спрямоване на теоретичне обґрунтування та емпіричне оцінювання потенціалу SMART-технологій, підсилених штучним інтелектом (ШІ), як стратегічних інструментів інтенсифікації професійної підготовки. Об’єктом дослідження є розроблення концептуальної моделі, що оптимізує ефективність навчання та розвиток професійних компетентностей в умовах цифрових викликів та безпекових ризиків.

Методи: Дослідження реалізовано за поетапним змішаним дизайном (mixed-methods), що поєднує теоретичний аналіз із широкомасштабним емпіричним розвідками. На початковому етапі проведено епістемологічний аналіз літератури з питань SMART-освіти та Індустрії 4.0 для визначення ключових теоретичних засад. Емпіричний етап передбачав всеукраїнське опитування 4 645 педагогічних працівників закладів професійної освіти з усіх макрорегіонів України, що забезпечило високу територіальну та експертну репрезентативність (понад 73% учасників мають професійний стаж 10 і більше років). Аналіз даних зосереджувався на ефективності цифрових інструментів в умовах воєнного стану, домінантних формах організації навчання та технологічних бар’єрах. На завершальному етапі застосовано структурно-логічне моделювання для синтезу отриманих результатів у концептуальну модель із чотирьох блоків, що інтегрує адаптивні алгоритми та предиктивну аналітику навчання для забезпечення точності та відтворюваності освітнього процесу.

Результати: Емпіричні дані свідчать, що SMART-комплекси виконують критичну стабілізуючу функцію: 86,1% педагогів відзначають значне або помірне прискорення темпів засвоєння знань та вмінь. Крім

того, 67,3% респондентів оцінили ці технології як високоефективні для підтримки безперервності освіти в умовах воєнного стану. Інтенсифікація досягається через цикли миттєвого зворотного зв'язку, автоматизацію рутинного оцінювання та персоналізацію навчальних траєкторій. У дослідженні запропоновано комплексну чотириблокову концептуальну модель:

1. технолого-адаптивна інфраструктура з використанням VR/AR та адаптивних модулів;
2. аналітико-прогностичний блок, що моніторить «цифровий слід» здобувачів;
3. система персоналізованої підтримки на основі генеративного ШІ та інтелектуальних тьюторів;
4. результативно-компетентнісний блок, узгоджений із вимогами ринку праці.

Хоча 75,8% учасників визнають позитивний вплив ШІ на якість освіти, суттєвими системними бар'єрами для повномасштабного впровадження залишаються нестабільний зв'язок, перебої в енергопостачанні та різний рівень цифрової грамотності персоналу.

Висновки: Дослідження доводить, що інтенсифікація професійної підготовки засобами SMART-технологій є швидше системною освітньою еволюцією, ніж просто технологічним оновленням. Запропонована модель сприяє переходу до «випереджального навчання», трансформуючи роль педагога з транслятора знань у дизайнера освітнього досвіду. Ефективна імплементація потребує двовекторної стратегії: модернізації інституційної цифрової інфраструктури та стимулювання стратегічної цифрової саморегуляції здобувачів. Теоретично це дослідження долає розрив між теоріями адаптивного навчання та професійною дидактикою. Практично результати пропонують масштабований план модернізації систем професійної освіти в регіонах, що постраждали від криз, встановлюючи нові стандарти для розвитку стійкого та технологічно просунутого людського капіталу.

Ключові слова: *стійкість, Індустрія 4.0, навчання на основі ШІ, освітній дизайн, цифрова грамотність, адаптивна педагогіка, освітня екологія.*

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