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# DESIGNING A SMART EDUCATIONAL ENVIRONMENT FOR THE PROFESSIONAL DEVELOPMENT OF SCIENCE AND MATHEMATICS TEACHERS

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***Abstract.*** *The digital transformation of education and the rapid development of artificial intelligence, Internet of Things technologies, learning analytics, and immersive tools require new approaches to the professional development of science and mathematics teachers. The aim of this study is to substantiate a SMART educational environment model for postgraduate professional development based on teachers' needs and requests. The study combines a literature review and modelling with an empirical survey of 292 Ukrainian school teachers. Descriptive statistics, Spearman non-parametric correlation analysis, principal component analysis, and clustering were used to interpret the responses. The findings show that teachers give priority to resource availability, high-quality content, professional networks, interactive learning, consultations, and online tutoring. Preferences also differ according to teaching experience, which supports the need for differentiated professional development trajectories. The proposed SMART educational environment integrates learning management platforms, artificial intelligence, learning analytics, adaptive digital resources, virtual and augmented reality tools, professional communities, personalised learning trajectories, and ethical principles of data and AI use. The model can support continuous professional development, strengthen digital and pedagogical competence, and provide a flexible framework for the modernisation of postgraduate science and mathematics education.*

***Keywords:*** *SMART educational environment, teacher professional development, postgraduate education, science teachers, mathematics teachers, artificial intelligence, learning analytics.*

## Introduction.

Modern STEM education faces the challenges of digital transformation, the need to improve teacher training and integrate the latest technologies into the educational process. In the context of the rapid development of information technologies, in particular IoT, AI, AR/VR, robotics, there is a need to create SMART educational environments that provide personalized, adaptive and immersive learning for the professional development of teachers of natural and mathematical disciplines, implement continuous, accessible and effective improvement of their pedagogical skills in the context of rapid change and the development of digital technologies and AI. Defining the structure of the SMART educational environment of postgraduate

education will contribute to creating an adaptive, personalized and innovative system of professional development for science and mathematics teachers, which ensures the improvement of their digital, STEM and research competence, the formation of interdisciplinary skills, critical thinking and innovative approaches to teaching.

**Literature review.**

The international scientific community uses various terms to describe the educational environment, reflecting the evolution of information and communication technologies and pedagogical approaches. The concept of Virtual Learning Environment (VLE) refers to learning platforms (e.g. Moodle or Blackboard) aimed at course management, electronic submission of materials and interaction between the teacher and students, but their functionality is often used in a simplified form - mainly as a repository of materials, which limits their pedagogical effectiveness (Ahmed et al., 2023). A more extended model is the Digital Learning Environment (DLE), which includes mobile applications, cloud services, collaboration elements and learning analytics (Zhang et al., 2024). Technology-Enhanced Learning (TEL) is considered a pedagogical model that uses innovative technologies (e.g. IoT) to improve traditional learning and formative assessment (Mäkelä et al., 2022). The latest stage—Smart Learning Environment (SLE)—integrates artificial intelligence, big data, sensors, and IoT to create a personalised, adaptive learning process with real-time support (Celik, 2023; Chinedu et al., 2024; Dmitrenko et al., 2023). The importance of SMART educational environments that provide personalised, adaptive and immersive learning (Dmitrenko et al., 2023) is growing in the context of the development of STEM education, which faces numerous challenges of digital transformation, among which the key ones are the need to integrate the latest technologies (IoT, AI, AR/VR, robotics) and improve the professional competencies of science and mathematics teachers. The basis of SMART environments is the integration of technologies with innovative pedagogy. Researchers emphasise that effective design should be based on the principles of flexibility, openness, accessibility and the development of digital competencies of teachers (Gros, 2016). The use of approaches such as learning-by-doing, flipped classroom, gamification, and involving users in co-design of the

educational process increases engagement and promotes the development of professional communities (Mäkelä et al., 2022). Researchers pay particular attention to developing STEM teacher competencies through the use of robotics, IoT, and AI, which contributes to the growth of technological literacy, the formation of critical thinking, and confidence in teaching (Kitcharoen et al., 2024). AI plays a key role, providing personalised learning, real-time feedback, and supporting interdisciplinary collaboration (Celik, 2023; Thanh et al., 2025).

The most effective strategies for overcoming the challenges of digital transformation of education were blended mentoring, professional communities, and mentoring (Johari et al., 2022; Buatip et al., 2019). The ethical dimension of implementing SMART environments using AI and IoT requires clear policies on privacy, transparency and inclusiveness to avoid inequalities of access (Vorotnykova, 2025; Chinedu et al., 2024). Researchers have identified challenges to using such environments: the lack of practice-oriented models that take into account the context of rural and resource-poor schools, as well as limited international collaboration that allows for the exchange of experiences and mutual learning (Zhang et al., 2024). Barriers to implementing SMART environments include lack of resources, time constraints, insufficient teacher training and technological incompatibility (Zhou et al., 2025). The modern evolution of educational environments can be traced from VLE as basic learning management platforms to system-ecological models, SLE create immersive, personalised spaces based on AI and IoT, in the future a socially-oriented approach to learning and integration of pedagogical design, learning analytics and ethical management of digital environments should be implemented. Researchers have not paid attention to postgraduate education, which requires the development of adaptive models of professional development, the development of digital, AI and STEM competencies of teachers, deepening inter-university cooperation, the use of available online simulators, laboratory workshops, etc. SMART educational environments are a promising tool for modernising the professional development of STEM teachers and require research into the combination of innovative pedagogical practices, technological infrastructure and systemic support at the level of educational

policy and the creation of a SMART educational environment model for the professional development of teachers of natural and mathematical disciplines.

The purpose of the study is to describe a SMART educational environment model for the professional development of science and mathematics teachers based on teachers' needs and requests. The objectives are to analyse teachers' needs concerning the professional development environment and to model a SMART educational environment for postgraduate science and mathematics education.

**Methodology.**

The study combines theoretical methods: literature analysis to develop a theoretical basis for the study and identify the problem to be solved, modelling of the SMART educational environment for professional development of science and mathematics teachers, and empirical methods: an online survey as a data collection method and statistical methods for processing the results, including non-parametric correlation analysis, cluster analysis of responses of science and mathematics teachers regarding effectiveness factors and functions of the information and educational environment of postgraduate education, and descriptive statistics. To collect data, a survey of 292 teachers of Ukrainian schools was conducted to determine their opinion on the information and educational environment for advanced training. The survey was conducted online with the anonymity of participants and included questions about the level of teachers' qualifications and their competencies and teachers' assessments of an effective environment for professional development and the prospects for using innovative technologies to improve it.

The study adhered to the basic ethical principles: voluntary participation with guaranteed anonymity and confidentiality of responses, before the survey began, respondents were informed about the purpose and conditions of the study, which provided for their informed consent; all data were used exclusively in a generalized form, without the possibility of personal identification, which ensures compliance with academic integrity and the rights of participants. Survey participants use various platforms for professional development and have a sufficient and high level of digital competence for assessing the environment of advanced training. Most science teachers

(62.8%) have more than 20 years of teaching experience, among mathematics teachers this figure is 47.3%. More than 40% of respondents have a teaching title, which indicates a high level of professionalism. The share of teachers of the highest category of science is more than 65%, mathematics - 37.8%. The digital competence of mathematics teachers was estimated on average at 8.19 points out of 10 for mathematics teachers, natural sciences - 7.91, which generally demonstrates a high readiness to work in the information and educational environment and its assessment.

**Results and discussion.** Statistical analysis of respondents' responses (n =292) regarding aspects that, in their opinion, need improvement in the information and educational environment of postgraduate education demonstrates the clear priorities of the pedagogical community. The option "Creating professional networks by subjects or industries" received the highest number of mentions (52.7%), confirming the high demand for a professional environment for exchanging experience, jointly developing materials and integrating modern approaches into practice. "Involving teachers in advanced training" was chosen by 28.1% of respondents, which can be interpreted as the need for motivational, organizational and personnel mechanisms that would stimulate the active participation of teachers in the continuous professional development of colleagues and the desire to cooperate. The items “Online tutoring” – 25.3% and “Teacher consultations” – 24.3% have similar results, indicating the need for targeted support, individualization of the educational route, and support for teachers throughout the educational process. Fewer respondents (9.9%) spoke in favor of improving the design and navigation of sites, and the ethics of data use, which indicates the secondary importance of ethical and aesthetic-functional aspects compared to problems of a content and organizational nature.

The most important factors influencing the effectiveness of the use of the information and educational environment were the availability of resources (77.1%), high-quality content (74.7%), which emphasizes the need for structured, reliable and relevant educational materials, and highly appreciated the importance of interactive learning (49.3%) for studying natural and mathematical disciplines, and noted that modern digital platforms should ensure the active participation of students in the

educational process, which indicates an orientation towards the basic functional components of the digital environment, rather than complex technical innovations. Analysis of teachers' needs allows us to understand which aspects of the SMART environment are priorities for different groups of users can be the basis for the formation of differentiated strategies in the development of digital educational products (see Fig. 1). The results obtained confirm the concept of differentiated educational needs of teachers depending on experience (Zhou et al., 2025): younger teachers are more inclined to innovation, older ones to institutional stability, which is consistent with the provisions of the theory of teacher professional development (Chai, 2019), which emphasizes the change of priorities at different stages of their career. Analysis of teachers' preferences by experience indicates a different orientation of professional needs: young teachers with up to 5 years of experience prefer interactive forms of interaction, professional networks and methodological support; the group with 5-10 years of experience focuses on the automation of the educational process and access to digital resources to increase efficiency; teachers with 10–20 years of experience combine traditional and innovative approaches, in particular, the organization of cooperation and the development of curricula; instead, teachers with over 20 years of experience demonstrate an orientation towards content quality, stable organizational support, and resource availability, with less interest in innovative features, which indicates a predominantly conservative style of professional development.

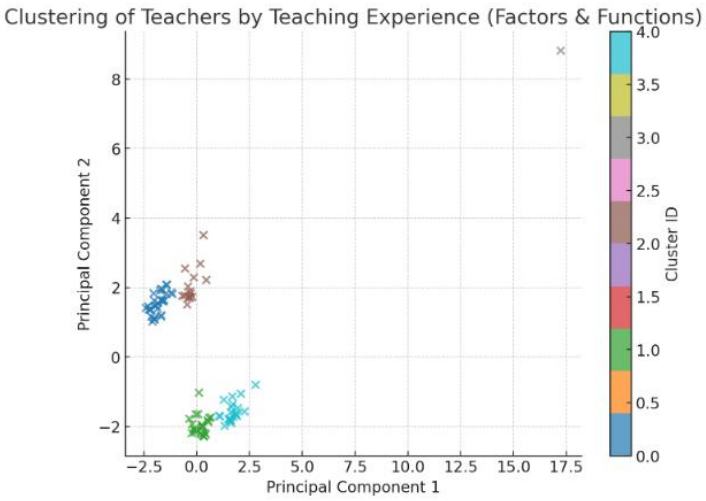



**Figure 1 - PCA analysis of the functions of the digital environment of postgraduate education**

The survey results demonstrate that the main value of the information and educational environment in postgraduate education is the creation of a professional community (73.3%) for the exchange of experience and the possibility of prompt access to relevant information (58.2%), ensuring flexibility and automation of learning (33.9%), and reducing the administrative burden on teachers (28.1%), which emphasises the need to develop educational environments focused not only on content, but also on interaction and support of pedagogical practices and personalisation of learning.

The most effective strategy, according to teachers, is the combined use of several communication channels. To identify the influence of the choice of self-study methods on the level of digital competence, non-parametric Spearman correlation analysis was applied, and the answers to the question “What methods do you consider the most effective for self-study within postgraduate education?” were analyzed, with each of the options chosen by the respondent coded as 1 (selected) or 0 (not selected). Next, correlation coefficients were calculated with the answers to the scaled question “Rate your level of digital competence” (scale from 0 to 10). Key results ($p < 0.05$). The strongest positive relationship is observed between participation in interactive online courses and digital competence ($\rho=0.212$, $p=0.001$), teachers with higher digital skills have a greater tendency towards platform-based, structured digital learning. There is also a significant positive relationship with the choice of webinars ($\rho=+0.179$) and video lessons ($\rho=+0.144$), these formats involve interactivity, convenience and require basic digital skills (registration, navigation, interaction), while traditional learning methods, such as independent reading of specialised literature, demonstrated a weak inverse correlation with digital skills ($\rho=-0.104$, $p=0.049$), which may indicate that teachers with a lower level of digital competence prefer offline formats or classic approaches.

To create the model, the study used a combination of development and research of educational solutions in a real context and presents the SMART educational environment of postgraduate natural and mathematical education as an interconnected network of resources, participants and technologies (See Fig. 2).

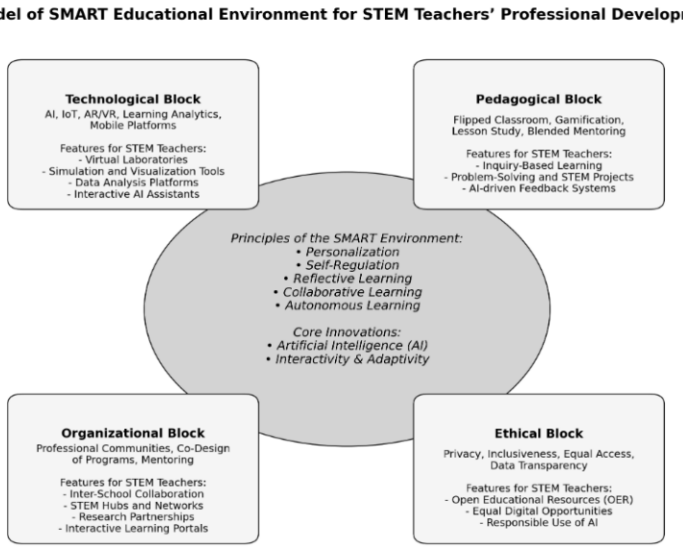



**Figure 2 - SMART educational environment of postgraduate science and mathematics teachers**

Interactivity is a critical factor for ensuring active inclusion of students in the learning process, feedback, development of critical thinking and personal involvement in learning. The result indicates a certain underestimation by teachers of the interactive potential of digital platforms. Perhaps some teachers perceive the digital environment primarily as a tool for delivering information, and not as an environment for interaction, collaboration and reflection. This interpretation correlates with the results of factor analysis (PCA), where "interactivity", "consultation", and "collaboration" formed a separate group, different from "providing materials" or "schedules". The results obtained are fully correlated with the modern conceptual principles of digital transformation of education, according to which an effective information and educational environment should be based on the principles of personalization, professional interaction and adaptability. To model the SMART educational environment, a systemic approach was used, considering the environment as a complex system with interconnected elements, the TPACK model (Technological Pedagogical Content Knowledge) (Chai, 2019) – integration of subject knowledge, pedagogy and digital technologies.

**Summary and conclusions.** The survey results are consistent with the conclusions of modern research (Zhang et al., 2024): it was found that the key factors in the effectiveness of information and educational systems are the quality of content,

platform accessibility and the availability of technical support, in particular, technical convenience, feedback and quality of teaching are crucial for a positive perception of digital educational environments (Gros, 2016; Zhou et al., 2025). “The use of digital resources when teaching educational material in advanced training courses requires taking into account a number of their features: interactivity (as a process from information exchange to action); multimedia and AI, AR/VR (representation of objects and processes using various formats); the ability to model real objects and processes for their research; communicativeness (the ability to communicate, the efficiency of information presentation, control over the state of the process by connecting computers into a network); productivity (achieving a result through one’s own independent activity)”. The survey data focus on the development of information and educational systems in terms of accessibility, content and interactivity as the main determinants of their effectiveness. The priority functions of the SMART environment are interactive forms of organising the educational process: interactive online courses (87.0%), lesson media libraries, virtual simulators (51.7%), which confirms the growing importance of distance learning platforms that combine structure, the possibility of flexible planning and access to certified materials and autonomy in learning. The SMART environment model allows you to increase digital and pedagogical competence, gain access to individualised development trajectories and professional communities, ensure the effective functioning of postgraduate education and compliance with international SMART education standards, and create conditions for continuous professional development and innovative updating of STEM education. The model includes the following blocks: infrastructure: LMS/VLE platforms integrated with mobile applications, IoT and big data; pedagogical strategies: flexible learning, gamification, project-based learning, adaptive courses; professional communities: uniting teachers in a collaboration network, peer-to-peer mentoring; learning analytics: personalisation of trajectories, monitoring of success and needs; and ethical standards: transparency of algorithms, protection of personal data, inclusive access. Despite the dominance of factors such as “availability of resources” (77.1%) and “quality of content” (74.7%), interactivity remains in the shadows, although its role in pedagogical practice is

extremely important. Interactive design of the learning environment using AI has a direct impact on satisfaction and learning outcomes and provides new opportunities for dialogue between participants in the educational process in the online environment as a key element of "mutual presence".. Prospects for further research include conducting longitudinal studies to track the dynamics of the development of professional skills of science and mathematics teachers in the context of using the SMART educational environment, as well as expanding the sample to other regions and educational levels to obtain representative data.

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