MONOGRAPH

INCLUSIVE TRANSFORMATION OF EDUCATION UNDER CONDITIONS OF INSTABILITY THROUGH EQUAL ACCESS, PARTNERSHIP INTERACTION, PERSONALIZED PEDAGOGICAL SUPPORT, AND EMOTIONAL SAFETY

Open Science Initiative

Inclusive Transformation of Education Under Conditions of Instability Through Equal Access, Partnership Interaction, Personalized Pedagogical Support, and Emotional Safety

Monograph

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INTRODUCTION

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The idea of inclusive transformation in education has become especially relevant at a time when educational systems are required to respond not only to long-standing inequalities, but also to new forms of instability. War, forced displacement, digital inequality, interrupted access to the Internet, psychological vulnerability, institutional uncertainty, and the need for flexible educational formats have changed the conditions in which educational institutions operate. Under such circumstances, inclusion cannot be understood solely as the formal presence of learners with special educational needs in a common educational space. It should be considered a broader principle of educational development that concerns access, participation, institutional responsibility, pedagogical flexibility, emotional safety, and the capacity of educational institutions to support every learner in changing conditions.

The chosen topic of this monograph is grounded in the need to bring together several dimensions of educational transformation that are often discussed separately. Equal access to educational resources, partnership interaction in educational institutions, personalized pedagogical support, digital flexibility, and emotional safety are not isolated areas of pedagogical work. They are interconnected components of a more resilient and human-centered model of education. If institutional access is not supported, it remains declarative. If partnership is not embedded in an educational institution's organizational culture, adaptation becomes fragmented. If personalization is reduced only to digital tools, it loses its pedagogical depth. If emotional support is ignored, inclusion may remain formally correct but psychologically unsafe.

The monograph proceeds from the assumption that inclusive transformation requires movement at several levels. At the institutional level, this involves developing policies, legal mechanisms, universal design, reasonable accommodations, digital accessibility, inclusive safety, and support services. At the organizational level, it requires partnership-based governance, participatory decision-making, cooperation among internal and external stakeholders, and adaptive educational practices. At the pedagogical level, it requires teachers who can personalize educational content, respond to diverse learning needs, support learners in offline or digitally unstable settings, recognize emotional states, regulate their own reactions, and maintain empathetic communication. These levels constitute the monograph's internal logic.

The first chapter, "Ensuring Equal Access to Educational Resources: An Inclusive-Institutional Approach under Conditions of European Integration," examines inclusion as a systemic and institutional issue. The chapter analyzes the development of social inclusion in higher education, the transition from a medical to a social and institutional model of disability, and the importance of removing barriers created by inflexible educational environments. Special attention is paid to European standards, universal design, reasonable accommodation, digital accessibility, inclusive safety, support mechanisms, and post-war reconstruction. The chapter shows that equal access is not limited to physical accessibility or isolated support measures. It requires a coherent institutional policy that integrates inclusion into governance, quality assurance, digital infrastructure, safety standards, and the everyday practices of higher education institutions.

The second chapter, "Partnership Interaction in a Modern Gymnasium: Organizational and Pedagogical Conditions and Adaptive Educational Practices," shifts attention from the institutional to the educational institution level. It examines partnership pedagogy as a basis for creating a safe, adaptive, and learner-centered educational environment. The chapter substantiates organizational and pedagogical conditions that support effective partnership interaction among teachers, learners, parents, administrators, and external partners. These conditions include teacher professional development, participatory governance, a matrix management model, collective planning of educational activities, innovation-oriented practices, stakeholder cooperation, and monitoring of partnership effectiveness. The chapter demonstrates that partnership is not only a communicative principle but also an organizational mechanism for strengthening educational resilience in the face of uncertainty.

The third chapter, "The Capacity of Future STEM Teachers for Personalized Learning in Inclusive Education under Unstable Internet Access," focuses on the professional readiness of future STEM teachers. It considers personalization not as a function of digital platforms alone, but as an integrated pedagogical capacity that combines methodological flexibility, inclusive sensitivity, digital-pedagogical maturity, emotional support, and the ability to act when digital resources are limited or unavailable. The chapter is based on the idea that unstable Internet access does not simply create technical difficulties. It also reveals whether a teacher can maintain the logic of personalization without relying entirely on online tools. Particular attention is given to offline adaptations, paper-based individual learning routes, alternative explanations, visual and manipulative support, differentiated tasks, and emotionally supportive communication.

The fourth chapter, "Emotional Intelligence of Future STEM Teachers as a Condition for Inclusive Interaction in a Digitally Unstable Educational Environment," deepens the analysis of pedagogical readiness by focusing on the emotional and communicative dimension of inclusive education. The chapter argues that STEM teaching requires not only subject knowledge, methodological competence, and digital skills, but also the ability to recognize learners' emotional states, regulate one's own reactions, communicate empathically, and respond constructively to digital disruptions. Particular attention is paid to situations in which technical instability affects learners with special educational needs, for example, when video communication is interrupted during interaction with a learner with a hearing impairment. The chapter shows that emotional intelligence is not an additional personal quality of a teacher, but a professional resource for maintaining inclusive pedagogical interaction.

Taken together, the chapters present inclusive transformation as a multidimensional process. It begins with the recognition of the right to equal access, continues through institutional and organizational restructuring of educational environments, and culminates in personalized, emotionally sensitive pedagogical action. This logic is especially important for Ukrainian education, which is developing under the pressure of war, digital inequality, forced adaptation, and European integration. The monograph, therefore, does not reduce inclusion to a narrow category of support for separate groups of learners. It treats inclusion as a principle of educational renewal that concerns the whole system, from legislation and institutional policy to the teacher's everyday decisions in direct interaction with learners.

Chapter 1.
ENSURING EQUAL ACCESS TO EDUCATIONAL RESOURCES: AN INCLUSIVE-INSTITUTIONAL APPROACH UNDER CONDITIONS OF EUROPEAN INTEGRATION

Kateryna Rumiantseva, Vitalina Pugach

Abstract. *The study examines the problem of ensuring equal access to educational resources in Ukrainian higher education institutions through an inclusive institutional approach. The purpose of the study is to substantiate the theoretical foundations for the development of social inclusion in the context of European integration, to develop a relevant concept, and to outline its implementation in the post-war period. The methodology is based on a comprehensive analysis of international practices, including the experience of the United Kingdom, Germany, and Poland, as well as the study of the European Union's regulatory and legal framework. The authors establish the need to move from the medical model of disability to a social-institutional model, in which the barrier is understood not as a person's health condition but as the inflexibility of the environment. The analysis demonstrates the effectiveness of the "personal budget" model and digital inclusion as instruments of learner autonomy. The study substantiates that the implementation of universal design standards and the principles of the Rome Communiqué is a strategic condition for modernizing higher education. The practical significance of the study lies in developing a "roadmap" for aligning Ukrainian legislation with the requirements of the European Higher Education Area.*

Keywords: *social inclusion; higher education; European integration; inclusive-institutional approach; reasonable accommodation; universal design; digital inclusion.*

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Introduction

In the context of global transformations and Ukraine's integration into the European Higher Education Area (EHEA), the inclusive institutional development of education is becoming not only a requirement of social justice but also a strategic condition for modernizing the entire higher education system. The contemporary academic paradigm requires a transition from the "medical model" of disability, which focuses on individual deficits, to a "social-institutional model," in which the main barrier is understood not as a learner's health condition, but as the inflexibility of the educational environment. As Mel Ainscow notes in *Developing Equitable Education Systems*, inclusion is not a static state, but a dynamic process of removing barriers to participation and achievement for all learners without exception (Ainscow et al., 2025). For Ukrainian higher education institutions, this process is complicated by the need to adapt simultaneously to EU standards and to overcome the legacy of post-discriminatory practices.

In recent years, social inclusion has been actively developing in Ukrainian higher education institutions. This process has been driven by the adaptation of Ukrainian legislation to European norms and by the signing of international human rights agreements. At the legislative level, the right of persons with special needs to education has now been established, and the creation of a barrier-free environment for their learning has also been provided for. Despite this legal framework, the practical implementation of support for such learners in Ukrainian universities remains unsystematic. Most higher education institutions still do not have specialized support centres; therefore, educational adaptations are often the result of individual initiatives by teachers rather than a well-established institutional mechanism. In addition, there is an acute shortage of assistive technologies, universal design principles, and coordinated work among specialists of different profiles. The main challenges to social inclusion in higher education stem from insufficient teacher readiness, a lack of resources, and the absence of unified support standards. Under these conditions, the analysis of international practices becomes particularly important, as it should provide the basis for creating a comprehensive and effective system of support for learners with special educational needs in Ukraine.

To address the stated problem and achieve the study's purpose, a comprehensive approach was adopted. It included a comparative analysis in which the provisions of Ukrainian legislation were compared with key EU documents, particularly Directive 2016/2102 and the Rome Communiqué of 2020, to identify gaps in the inclusive policies of Ukrainian universities. The institutional method was also used, enabling consideration of a higher education institution as an integrated system in which inclusion is implemented not as a set of isolated measures, but across governance, infrastructure, and digital content. The modeling and forecasting methods were applied based on successful cases from European countries. This enabled the development of a conceptual model of inclusive institutional development for Ukrainian higher education institutions in the post-war period.

The main sources of the study were official reports of the European Higher Education Area (EHEA), the provisions of the National Strategy for the Development of Inclusive Education until 2029, and monitoring results on the accessibility of university web resources. The analysis was carried out by systematizing international practices and critically assessing them in relation to the current situation in Ukraine.

The study's design is based on the principle of moving from the general to the specific. The first stage is devoted to the analysis of theoretical models of inclusion and their transformation under the influence of digital technologies. The second stage involves a critical review of European experience, with particular attention to mechanisms that ensure learners' autonomy, including those of the United Kingdom and Poland. The final stage focuses on developing practical recommendations for Ukrainian higher education institutions, covering both physical accessibility and the digital inclusiveness of educational content. Such a structure enables not only the identification of existing problems but also the formulation of a coherent strategy for inclusive institutional development.

The expected results and their scientific significance lie in moving beyond a purely formal approach to inclusion. First, the study conceptualizes reasonable accommodation not as a one-time measure but as a dynamic standard of educational quality that accounts for each learner's educational trajectory. Second, it substantiates universal design as a foundation for creating a barrier-free environment, from architecture to the interfaces of distance learning systems, which benefits all participants in the educational process, not only specific groups. Third, it identifies innovative support mechanisms: developing proposals for "personal budgets" and specialized digital services will lay the groundwork for learners with special educational needs (SEN) to achieve financial and technological autonomy.

The practical value of the study lies in the transition from declarative statements to effective institutional tools. Regarding the implementation of state strategies, the findings will provide a theoretical basis for the realization of the National Strategy for the Development of Inclusive Education until 2029 and support its alignment with European requirements. As a model for post-war recovery, the proposed conceptual model of inclusive-institutional development may serve as a basis for adapting higher education institutions to new realities. This includes creating inclusive hubs and support centers that can provide psychological and physical rehabilitation for veterans and individuals affected by hostilities within the educational process.

The European integration vector of the study is reflected in the proposed steps, which will contribute to the recognition of Ukrainian educational standards at the EU level, making higher education institutions more open, competitive, and human-centered.

For the purposes of this study, inclusive institutional development is understood as a multidimensional process operating at three interrelated levels. The first level is normative and legal. It concerns harmonizing Ukrainian legislation with international and European standards, including the principles of non-discrimination, reasonable accommodation, universal design, and digital accessibility. The second level is institutional. It concerns the capacity of higher education institutions to transform legal requirements into stable organizational mechanisms, such as support centers, accessibility policies, inclusive quality assurance procedures, and coordinated cooperation among administrative, academic, psychological, and technical units. The third level is practical and pedagogical. It concerns the direct support of learners through academic adaptation, assistive technologies, flexible educational trajectories, psychological support, and accessible digital content. The interaction of these three levels makes it possible to consider equal access not only as a declared right, but also as a system of institutional obligations and practical mechanisms that determine the quality of higher education.

Research Results

The term "social inclusion" began to be used actively in Europe and globally in the early 1960s.

The analysis of contemporary scholarly literature shows that "in the second decade of the twenty-first century, experts, researchers, and scholars interpret social inclusion in different ways, although with increasing conceptual precision. For example, the EU initiative, the European Pillar of Social Rights of 2017, aimed at building a strong social Europe in the twenty-first century that is fair, inclusive, and full of opportunities, combining social inclusion and social protection into a single category. In the concept of the European Pillar of Social Rights, the category 'Social Protection and Inclusion' is ensured through access to basic services, housing, social protection and health care, minimum income and unemployment benefits, childcare, pensions for older people, assistance for homeless persons, and the inclusion of persons with disabilities" (Orzhel et al., 2024).

Another interpretation of social inclusion was proposed by the World Bank. In the study *Inclusion Matters: The Foundation for Shared Prosperity*, two definitions of social inclusion are presented:

1. the process of improving the terms on which individuals and groups take part in society;
2. the process of improving the ability, opportunity, and dignity of people, disadvantaged on the basis of their identity, to take part in society.

According to the World Bank’s concept, social inclusion is ensured through access to three important spheres of life: markets, services, and spaces. These include land, housing, labor, and financial markets; social, information, transport, and educational services; health care; water and electricity supply; and other services, as well as political, physical, cultural, and social spaces. Access to markets, services, and spaces largely depends on education” (Orzhel et al., 2024).

In our view, the development of social inclusion in higher education institutions in Ukraine should be considered a dynamic, multidimensional process that is currently moving from formal legal recognition to concrete changes within these institutions. In this regard, the transformation of approaches in the European educational space is particularly indicative, as inclusion there has long gone beyond purely regulatory frameworks.

The experience of European Union countries in inclusive higher education demonstrates a transition from basic architectural accessibility to the creation of comprehensive ecosystems of learner support. In academic discourse, this process is often described through the concept of the “social dimension,” which implies that the composition of the student body should fully reflect the diversity of society.

Based on individual countries' experiences, several key strategies can be identified that Ukraine may adapt in its European integration strategy.

For example, in the Scandinavian countries, particularly Sweden and Denmark, inclusion is based on the principle of full state responsibility. These countries have developed a network of special-needs coordinators who support learners from admission through graduation. Scholars such as Göran Söderlund note that the success of the Swedish model lies in its decentralized resource allocation, in which each university receives targeted funding to support personal assistants, sign language interpreters, or specialized software (Söderlund et al., 2024). This approach makes inclusion a natural part of university life rather than an exception.

Germany demonstrates another, more structured approach through the system of student support organizations known as

Studentenwerke. These organizations are responsible not only for the educational process, but also for social and everyday aspects of student life. This includes creating inclusive student residences with rooms equipped in accordance with universal design standards, as well as providing consultations on study funding through special grants. Legally, the German system is based on the Framework Act for Higher Education, which obliges universities to ensure equal rights for learners with disabilities without any restrictions regarding their choice of specialty.

In the context of inclusive institutional development, the British Disabled Students' Allowance (DSA) model is of particular interest (Department for Education, 2023). Its main legal difference from the Ukrainian system lies in the transition from institutional funding to direct subsidization of a specific learner's needs.

The Disabled Students' Allowance is a state grant regulated by the Education (Student Support) Regulations. Unlike general social benefits, the DSA is not a substitute for income. It has a clearly defined legal purpose: to cover additional costs that arise directly from a student's need for inclusive support. The mechanism for transferring funds is based on an individual entitlement, meaning that the right to receive funds belongs to the learner, not to the university. This implements the principle that "money follows the learner," which differs fundamentally from the Ukrainian approach, where budgetary funding for inclusion is often absorbed into the institution's general expenditures. Under the DSA model, a needs assessment is conducted, and funds are allocated only after an independent audit of needs has been carried out by a certified center, which legally confirms the objectivity of the expenses.

British legislation clearly distinguishes the areas in which these funds may be used, allowing the learner to independently form their own support ecosystem:

1. Non-medical helper allowance: payment for the services of assistants, readers, and sign language interpreters. The learner chooses the service provider independently, which creates a market for high-quality support services.

2. Specialist equipment allowance: funds for the purchase of personal technical aids, such as screen readers or ergonomic equipment, which remain the property of the learner.
3. Additional expenses: payment for specific costs, including copying materials or specialized transport.

In comparison with Ukrainian Resolution of the Cabinet of Ministers No. 635 (Cabinet of Ministers of Ukraine, 2019), several critical points can be identified, primarily autonomy and dependence. In Ukraine, the learner depends on the higher education institution's capacity to provide support, including the availability of an assistant on staff or the institution's purchase of equipment. In the United Kingdom, through the DSA, the learner becomes an autonomous subject who "purchases" the necessary services, thereby reducing the problem of institutional inertia. The Ukrainian model provides for allocating funds to the institution, for example, to support an inclusive group of up to 3 persons. By contrast, the British DSA model focuses on personalization: if a learner needs a specific program that is not available at the university, they can purchase it using grant funds.

The implementation of elements of a personal budget in Ukraine within the framework of the National Strategy until 2029 would require amendments to the Budget Code, a transition from financing staff positions, such as assistants in higher education institutions, to a mechanism of direct subsidy for the learner, and regulation of the status of an assistant. This means legally recognizing an assistant as an independent service provider, rather than merely a university employee. Therefore, the "personal budget" model represented by the DSA demonstrates the highest degree of implementation of the social-institutional model. It transforms the learner from an object of care into a subject who manages their own educational process, which is one of the ultimate aims of the European integration of Ukrainian higher education.

The experience of Poland, which has undergone rapid institutional transformation, is also of interest for Ukraine. Polish higher education institutions use a system of disability grants (*dotacja na niepełnosprawność*). The more learners with officially documented special needs a university has, the more funding the institution receives for developing inclusive infrastructure. Joanna Głodkowska, in *Inclusive Education: Unity in Diversity*, emphasizes that this mechanism fostered healthy competition among universities to attract learners with special educational needs, leading to rapid improvements in campus accessibility (Głodkowska, 2020).

An important component of the European experience is also the implementation of digital inclusion. In the Baltic countries, particularly Estonia, all university learning materials are expected to comply with accessibility standards by default, including subtitles for video lectures, text descriptions for images, and adaptation for screen readers. This ensures equal access to knowledge in distance-learning conditions, which is highly relevant to the current Ukrainian situation.

These examples show that inclusive development is not only about changing laws, but also about creating financial and social incentives for universities.

The application of international experience in Ukraine requires consideration of the sociocultural background, available resources, and the autonomy of higher education institutions. A priority should be the development of unified standards to support learners with inclusive needs, thereby improving their learning outcomes and professional integration. For the reform of higher education in Ukraine, the following aspects of international experience are of particular importance: the creation of official university support services for learners with special educational needs, the implementation of universal design in the educational process, the targeted development of teachers' inclusive competence, and the establishment of comprehensive cooperation among all structural units of higher education institutions.

An analysis of European practices allows us to distinguish several complementary models of support relevant to Ukraine. The first may be defined as a service-coordination model. It is represented by the Scandinavian and German experience, where inclusion is ensured through specialized coordinators, student support services, accessible residences, and institutional mechanisms of academic and social assistance. The second is a financially personalized model, most clearly represented by the British Disabled Students' Allowance, in which support is linked to the individual needs of the learner rather than to the average needs of the institution. The third is a digitally standardized model, based on the requirement that digital resources, platforms, e-books, websites, and mobile applications comply with accessibility standards by default. For Ukraine, these models should not be considered as mutually exclusive alternatives. Their combined implementation may provide a basis for a coherent, inclusive ecosystem in higher education, where legal guarantees are supported by institutional services, targeted funding, accessible digital infrastructure, and personalized educational support.

The formation of inclusive policy in Ukraine is based on the principles embedded in international acts that the state has ratified and implemented into its own legal system.

The UN Convention on the Rights of Persons with Disabilities, particularly Article 24, is not merely a declaration, but a legal foundation (United Nations, 2006). The main requirement of Article 24 is that states must ensure an inclusive education system at all levels. The key term here is "reasonable accommodation." In the context of higher education institutions, this means that a university cannot refuse an applicant solely because appropriate conditions are absent. On the contrary, the institution must modify its environment, for example, by moving a lecture to the ground floor or providing a sign language interpreter, to ensure the right to education.

The EU Strategy for the Rights of Persons with Disabilities 2021–2030 introduces the concept of universal design (Cabinet of Ministers of Ukraine, 2024). Unlike "accommodation," which is provided for a specific person, universal design requires educational content and space to be created as accessible to everyone from the outset. For example, video lectures with subtitles are useful not only for persons with hearing impairments, but also for international students.

The Association Agreement between Ukraine and the European Union is also an integral part of the development of inclusive-institutional education in the context of European integration. In the field of higher education, Article 431 obliges

Ukraine to reform its education system in accordance with the principles of the Bologna Process (Association Agreement..., 2014). One of the central reference points here is the "social dimension," which requires higher education to be accessible to all social groups. Ukraine must implement the ESG and the Standards and Guidelines for Quality Assurance in the European Higher Education Area (European Association for Quality Assurance in Higher Education, 2015), which include inclusiveness as an integral part of internal quality assurance in universities.

The formation of inclusive institutional development in this context should be understood as the creation of a system of reasonable accommodation and universal design that makes the educational space accessible, flexible, and inclusive for all participants in the academic process. This approach can be observed in the example of Directive 2000/78/EC, which should be regarded not merely as an anti-discrimination act, but as a fundamental legal instrument that has transformed European educational law. Although the Directive formally concerns employment, its provisions have become a benchmark for the higher education sector regarding reasonable accommodation.

A detailed analysis of Directive 2000/78/EC in the context of inclusive institutional development in education should begin with the legal qualification of reasonable accommodation under Article 5 (Council Directive 2000/78/EC, 2000). This is a key provision of the Directive that Ukraine is implementing into its own legislation. The essence of this provision is that the Directive obliges institutions to take effective and practical measures to ensure that a person with a disability has access to education, provided that such measures do not impose a disproportionate burden on the institution. It is important to emphasize that, according to the case law of the Court of Justice of the European Union, the proportionality of such a burden is assessed with regard to financial and other costs, as well as the size and financial resources of the organization. This directly corresponds to the need to create financial incentives for universities.

The prohibition of indirect discrimination, established in Article 2 of the Directive, introduces a concept that is critical to the analysis of the inflexibility of the educational environment. Indirect discrimination occurs when an apparently neutral provision, criterion, or practice places persons with disabilities at a disadvantage compared with other persons. In higher education, for example, a requirement to take an examination only in written form, without the option to use assistive technologies, may constitute indirect discrimination, even if it is formally applied to all learners equally.

Positive action, provided for in Article 7 of the Directive, allows Member States to adopt measures to prevent or compensate for disadvantages linked to disability. In institutional terms, this legitimizes quota systems, special admission conditions, and additional funding, such as the Polish disability-grant model. This provision also supports the legitimacy of special conditions for learners with special educational needs in Ukrainian higher education institutions, as established by Resolution No. 635 of the Cabinet of Ministers of Ukraine.

The burden of proof, as addressed in Article 10, is a significant rule for protecting learners' rights. Its mechanism provides that when a learner presents facts that make it possible to presume the existence of discrimination, for example, the failure to provide an individual educational plan, the burden of proving the absence of discrimination shifts to the university. The introduction of this rule into Ukrainian practice requires higher education institutions to maintain careful documentation of every step taken to ensure inclusion, thereby transforming inclusion into an imperative of institutional functioning.

The analysis of Directive 2000/78/EC allows us to conclude that it functions as a legal mechanism that transforms inclusion from an ethical obligation into a strict legal requirement. For Ukraine, this means not only declaring rights but also creating procedural guarantees for their protection, as envisaged by the Strategy until 2029.

In addition to Directive 2000/78/EC, it is necessary to consider acts regulating digital and institutional accessibility, which are now among the European Union's priorities. The European Accessibility Act, Directive (EU) 2019/882, in the context of higher education, enables the transition from architectural barrier-free access to full digital inclusion of educational content. Although the Directive is oriented toward the market for goods and services, its influence on the academic environment is fundamental because it standardizes the resources learners use.

A detailed analysis of the key aspects of Directive (EU) 2019/882 shows that, in the educational context, its scope encompasses digital products critical to modern higher education, such as e-books and specialized software. Article 2 establishes that all e-books and the software used to read them must be accessible (Directive (EU) 2019/882, 2019). This means that university libraries and publishers are obliged to ensure that literature is compatible with screen readers and that text formatting can be modified. Since many universities use paid platforms to access academic databases, these interfaces must also meet strict accessibility criteria. Annex I of the Directive introduces the principle of "functional performance criteria," which goes beyond a simple technical description. Information must be presented in a way that can be perceived through multiple sensory channels, for example, by including mandatory text descriptions for graphs in academic papers. The interfaces of educational platforms must be predictable, and the content must be easy to perceive, which is particularly important for learners with cognitive disorders or dyslexia.

As a result, the implementation of Directive (EU) 2019/882 creates new legal obligations for Ukrainian higher education institutions within the framework of European integration and the National Strategy until 2029. These obligations concern the standardization of procurement. When purchasing computer equipment or licenses for learning management systems (LMS), universities must legally comply with the accessibility requirements established in the Directive. This also encourages a transition from isolated accommodation to creating content that is accessible to all from the outset. Directive (EU) 2019/882 refers to the EN 301 549 standard, which describes in detail the technical parameters of ICT accessibility, including requirements for contrast, subtitles in video lectures, and navigation without a mouse. This is important as evidence that inclusion is moving from the category of a "humanitarian aspiration" to the level of a technical regulation. Similar to Directive 2000/78/EC, this Act contains a reservation concerning financial capacity: when ensuring full accessibility requires a fundamental alteration of a product or imposes a disproportionate financial burden, an organization may be exempted from certain obligations. This creates a risk zone in which educational institutions may avoid change by referring to a lack of funds. Therefore, for Ukraine, it is important to combine these norms with the Polish model of targeted funding for inclusion.

The European Accessibility Act completes the formation of the inclusive institutional framework by making digital barrier-free access a mandatory legal requirement. For Ukrainian higher education institutions, this means a full review of electronic learning resources to ensure compliance with EU standards by 2029.

The analysis of the Rome Communiqué of 2020 in this monograph substantiates the transition from inclusion as a separate social project to inclusion as a fundamental component of the strategic management of every university. This is a key stage in aligning Ukrainian education with the European Higher Education Area (EHEA).

For the first time at a high political level, the Rome Communiqué approved the "Principles and Guidelines to Strengthen the Social Dimension of Higher Education in the EHEA" (Rome Communiqué, 2020). According to this document, the social dimension means creating conditions in which the composition of the student body at all levels and in all fields of education reflects the diversity of the population. This definition shifts the focus from "providing assistance" to "ensuring representativeness." For Ukraine, it provides a normative basis for expanding the system of quotas and special admission conditions envisaged in the National Strategy until 2029. The main requirement of the Rome Communiqué is that inclusion should not be an "addition" to the core activities of a university. Therefore, universities are obliged to integrate inclusiveness into their long-term development strategies, quality assurance plans, and budget planning. As a result, inclusion in Ukraine becomes an imperative requirement for accreditation. If inclusiveness is not embedded in a higher education institution's strategy, the institution does not comply with the Bologna Process standards.

It is appropriate to identify three fundamental principles of the Rome Communiqué that should be implemented in Ukraine. The first is a holistic approach, which means inclusion should cover not only classroom access but also teaching methods, counseling, financial support, and the institution's cultural environment. The second is the flexibility of educational trajectories. The document requires the creation of flexible learning pathways, which, in Ukrainian legislation, are implemented through the Individual Educational Plan (IEP) in accordance with Resolution No. 635 of the Cabinet of Ministers of Ukraine. The third principle is the need for states to collect reliable data on the participation of vulnerable groups in education. This legally substantiates the need to establish inclusion-monitoring systems in Ukraine at the Unified State Electronic Database on the education level.

When comparing the requirements of the Communiqué with the Ukrainian situation, it can be argued that Ukraine has already laid out a "roadmap" for these changes through the National Strategy until 2029, which, in fact, serves as an instrument for the direct implementation of the Rome Communiqué. However, a significant gap remains. The main challenge is the transition from formal compliance with requirements, such as the presence of a ramp, to a real transformation of academic culture, including universal design in teachers' thinking, as required by the EU Strategy for the Rights of Persons with Disabilities.

Thus, the Rome Communiqué of 2020 gives inclusion the status of a mandatory element of institutional autonomy and responsibility of higher education institutions. For this study, this serves as evidence that the formation of inclusive institutional development in Ukraine is an irreversible process, determined by its participation in the European Higher Education Area.

The analysis of Directive (EU) 2016/2102 on the accessibility of the websites and mobile applications of public sector bodies enables an expansion of the discussion regarding the digital transformation of higher education. This document is critically important because it directly classifies public universities as entities obliged to ensure the inclusiveness of their virtual space. Directive (EU) 2016/2102 establishes that accessibility is not merely a convenient website interface, but the full functionality of all digital resources (Directive (EU) 2016/2102, 2016). This includes the following:

1. Educational platforms (LMS): systems such as Moodle or Google Classroom used by universities must be fully adapted for screen readers and keyboard-only navigation.

2. Administrative services: applicant electronic accounts, course registration systems, and online libraries must comply with barrier-free accessibility standards.

3. Mobile applications: any official applications of higher education institutions, including schedules and campus maps, fall within the requirements of the Directive.

The Directive legally references the EN 301 549 standard, which is based on the international Web Content Accessibility Guidelines (WCAG) 2.1. It also introduces two important procedural tools that Ukraine should implement within the framework of the National Strategy until 2029. The first is the Accessibility Statement, under which each university must publish a detailed report on the accessibility status of its resources on its website, indicating which elements still require adaptation. The second is a feedback mechanism, according to which a student must have the legal right to report inaccessible content and receive a response within established time limits. In addition, Article 5 of the Directive allows temporary derogations from the requirements if they create a disproportionate burden for the institution.

From a legal perspective, this means that a university must conduct a financial and technical analysis to prove the impossibility of immediate adaptation. However, according to the Rome Communiqué of 2020, such derogations should be the exception rather than the rule. Therefore, a risk for Ukraine is that this provision may be used by higher education institutions to delay digital transformation. For this reason, this criterion should be clearly regulated in Ukrainian legislation.

In summary, the integration of Directive (EU) 2016/2102 into Ukrainian legislation serves as the basis for implementing the requirements for digital accessibility set out in Resolution of the

Cabinet of Ministers of Ukraine No. 635. It provides the technical content of the concept of universal design in the digital environment. Compliance with this Directive also becomes part of the internal quality assurance system in education, in accordance with the ESG, and transforms digital accessibility from an “additional option” into a strict administrative and legal requirement. For Ukrainian higher education institutions, this means not only the physical modernization of campuses but also the creation of an inclusive virtual learning space that complies with EU standards by 2029.

It is also necessary to analyze in detail the National Strategy for the Development of Inclusive Education until 2029, which defines the long-term development direction and the gradual removal of barriers across the entire educational system. For a comprehensive legal characterization, it should be considered a strategic policy document that determines the direction of state policy in inclusive education within the context of European integration. The National Strategy is a strategic planning effort. It has a comprehensive character and is not a law of direct application; however, it serves as a mandatory reference point for the legislative activities of the Cabinet of Ministers of Ukraine and relevant ministries.

The Strategy is based on the requirements of the UN Convention on the Rights of Persons with Disabilities, in particular Article 24, and aligns with the provisions of the Association Agreement between Ukraine and the European Union on the modernization of higher education institutions. The document serves as a “roadmap” that transforms international standards of inclusion into specific objectives for the Ukrainian legal system until 2029. The Strategy confirms the rejection of outdated approaches to the regulation of the education of persons with special educational needs (SEN). It finally legitimizes the transition from the medical model of disability, or the deficit-based approach, to the social-institutional model. This rights-based approach focuses not on the student’s health condition, but on the institution’s obligation to remove barriers.

The Strategy also specifies the right to reasonable accommodation, defining the failure to provide such accommodation, for example, the absence of sign language interpretation or architectural inaccessibility, as direct discrimination. One of the key aspects of the Strategy is the connection between inclusiveness and the quality of higher education. According to the logic of legislative development embedded in the Strategy, the accessibility of the educational environment becomes a mandatory condition for the accreditation of educational programs. This transforms inclusion from a voluntary initiative into an imperative requirement for the functioning of higher education institutions. The Strategy directs the system toward implementing European quality assurance standards, namely the *Standards and Guidelines for Quality Assurance in the European Higher Education Area*, in which inclusiveness is an integral criterion of internal university evaluation.

The Strategy until 2029 is a key instrument for synchronizing Ukrainian law with EU law. Unlike isolated accommodation, the Strategy promotes universal design in education, requiring the creation of content that is accessible to all users by default. Thus, the document aligns with the strategic goal of the Bologna Process, which is to ensure that the composition of the student body fully reflects the diversity of society. The National Strategy through 2029, therefore, provides a legal foundation for creating a coherent support ecosystem within Ukrainian higher education institutions. It transforms inclusion into a strategic condition for modernizing the higher education system under the conditions of integration into the European Higher Education Area.

In recent years, Ukraine has made significant progress in aligning its national legislation with European requirements. In particular, the Law of Ukraine "On Higher Education" (Verkhovna Rada of Ukraine, 2014) considers inclusion through the prism of educational quality. Non-compliance with accessibility requirements may serve as grounds for refusing accreditation of an educational program. This transforms inclusiveness from the "goodwill" of a higher education institution's administration into a mandatory condition for its lawful functioning.

Resolution No. 635 of the Cabinet of Ministers of Ukraine, which establishes the procedure for organizing inclusive education in higher education institutions, is the most detailed mechanism for translating legal norms into specific administrative actions by higher education institutions (Cabinet of Ministers of Ukraine, 2019). It provides for the following:

1. Inclusive groups: the procedure stipulates that, for effective learning, one group should include no more than three persons with special educational needs. This is intended to ensure that the teacher can give sufficient attention to each learner, in line with European standards for pedagogical workload.
2. Individual Educational Plan (IEP): The resolution establishes the student's right to adapt the schedule and methods of learning. For example, if a student requires more time to complete tasks due to physical or cognitive characteristics, this should be documented in the IEP.
3. Assistant of the learner: the document distinguishes between academic support and social or everyday assistance, allowing assistants to be involved in providing technical help during classes.

An assessment of Resolution No. 635 shows that this document transforms abstract "social justice" into an algorithm for administrative actions. It ensures the transition from simple architectural accessibility to the creation of a coherent support ecosystem, which is a necessary step for Ukraine's integration into the European Higher Education Area.

To substantiate the thesis that inclusive norms are mandatory for the lawful functioning of higher education institutions, it is also necessary to analyze the control instruments that transfer inclusion from the sphere of a "social mission" to the sphere of legal responsibility. This analysis can be carried out along two main vectors: the academic vector, represented by the National Agency for Higher Education Quality Assurance (NAQA), and the technical and construction-related vector, represented by the State Building Standards of Ukraine.

The Regulation on the Accreditation of Educational Programs in Higher Education, implemented by the National Agency for Higher Education Quality Assurance, is the main instrument of external quality control. The legal characterization of Criterion 9, "Learning Environment and Resources" (Verkhovna Rada of Ukraine, 2017), establishes a direct relationship between the successful accreditation of an educational program and the existence of an inclusive environment. According to the accessibility requirement, the institution must confirm not only the availability of resources but also their alignment with the needs of learners with special educational needs. Legally, this means that inclusion is a determinant of the legitimacy of educational activity. If a higher education institution does not ensure architectural and digital accessibility, its educational program cannot be accredited, which in turn makes it impossible to issue state-recognized diplomas. Thus, state control through the accreditation system makes inclusiveness an imperative. During accreditation visits, NAQA expert groups examine not only the presence of ramps but also the accessibility of library collections, the adaptation of the distance-learning system, and staff qualifications. This encourages higher education institutions to develop inclusion systematically rather than episodically.

Technical and legal control is provided through DBN V.2.2-40:2018, "Inclusiveness of Buildings and Structures" (Ministry of Regional Development, 2018). The adoption of these standards was a significant step, as they are mandatory according to the Law of Ukraine "On Building Standards." Inclusion has therefore ceased to be an evaluative concept and has acquired mathematically measurable characteristics. For example, doorways must be at least 0.9 meters wide to allow free wheelchair access. The slope of ramps is clearly limited to 8% at external entrances, ensuring safe and independent movement. Tactile navigation is also required, including tactile floor strips and Braille signs for persons with visual impairments. In terms of legal responsibility, violations of these standards during the design, construction, or operation of buildings at higher education institutions entail administrative liability. Moreover, under the licensing conditions, the absence of an act confirming compliance of the premises with accessibility-related building standards may constitute grounds for revoking a license for educational activity.

This confirms the thesis of institutional transformation, according to which a university is regarded not only as an educational center but also as a public space that must, by default, be safe and accessible to all categories of citizens.

The analysis of these regulations allows us to conclude that the combination of accreditation control through NAQA and technical regulation through the State Building Standards creates a "double framework" of responsibility for higher education institutions. This includes academic responsibility, meaning the impossibility of accrediting a program without inclusive resources, and administrative and economic responsibility, meaning the impossibility of legally operating buildings without compliance with physical accessibility standards.

These control instruments are a logical continuation of Resolution No. 635, as they ensure its implementation through real sanctioning and regulatory mechanisms. This ultimately confirms Ukraine's transition to the European model of inclusive development, in which human rights are protected not only by declarations but also by strict technical and legal standards.

The study confirms that the formation of inclusive institutional development in higher education in the context of Ukraine's European integration is a systemic process of transition from a philanthropic to a rights-based model. This transformation is based on three fundamental dimensions.

First, there is the regulatory and legal imperative. Through the implementation of Directive 2000/78/EC and the principles of the Rome Communiqué of 2020, inclusion in Ukraine has finally been transformed from a "voluntary social initiative" of a higher education institution into an imperative condition for its legitimate functioning. The analysis of NAQA criteria and Resolution of the Cabinet of Ministers of Ukraine No. 635 shows that non-compliance with accessibility standards, both architectural and digital, now entails direct legal consequences, ranging from refusal to accredit educational programs to the revocation of licenses.

Second, there is technological and digital convergence. The European Accessibility Act (Directive (EU) 2019/882) and the European Accessibility Act (Directive (EU) 2016/2102) establish a new standard for Ukrainian higher education institutions: the transition to universal design. This means that the inclusiveness of the digital educational space, including LMS platforms, online libraries, and mobile applications, should not be provided only upon a student’s request, but should be an embedded characteristic of the educational product by default.

Third, there is economic personalization. The analysis of the British personal budget model, represented by the Disabled Students’ Allowance (DSA), and the Polish experience indicates the need for further reform of Ukrainian financial law. The key direction should be a shift from financing the “average needs of the institution” to the direct subsidization of a specific learner's needs. This would reduce institutional inertia and give students real autonomy in choosing support options.

The National Strategy for the Development of Inclusive Education acts as the legal bridge that should ultimately synchronize Ukrainian legislation with the requirements of the European Higher Education Area (EHEA). However, the success of this strategy depends not only on improving technical regulations, such as the State Building Standards, but also on overcoming institutional inertia by embedding inclusion into the development strategy of every university as an integral part of academic culture.

Thus, inclusive institutional development is not only a requirement of the time but also a marker of the capacity of Ukrainian higher education institutions to become full and competitive elements of the global educational environment, where the right to education is realized through the actual removal of barriers rather than their formal recognition.

After the adoption of the Law “On Higher Education,” the Strategy for the Development of Higher Education in Ukraine for 2021–2031, the National Strategy for the Development of Inclusive Education for 2020–2030, and a number of other resolutions, inclusion became a mandatory component of the development strategy of every higher education institution.

This applies not only to learners with inclusive needs, but also to internally displaced persons (IDPs), veterans, representatives of ethnic minorities, and persons who have found themselves in difficult life circumstances.

At the same time, the Strategy for the Development of Higher Education in Ukraine for 2021–2031 defines the main priorities for higher education development, including inclusiveness, accessibility, equality, and diversity (Voronina-Pryhodii, 2025). Among the five strategic goals, two are related to the priority of social inclusion: ensuring high-quality educational and research activities and competitive higher education accessible to different segments of the population; and ensuring effective governance in a socially responsible higher education system.

There is no doubt that inclusion and equality can also potentially improve the quality of education within the national education system.

We are also convinced that social inclusion is a process that ensures equal opportunities for all learners to realize their life potential.

At the same time, it should be noted that, for post-war Ukrainian society, the most relevant group to which social inclusion measures will apply will be learners with special educational needs and/or disabilities. This group includes citizens with different experiences and war-related trauma, such as military personnel, veterans, internally displaced persons, citizens who lived in occupied territories, citizens who left Ukraine and later returned, people who lost friends, relatives, family members, employment, or property, persons who experienced physical and psychological trauma during martial law, children and relatives of the above-mentioned persons, and other social groups and categories of citizens in the country as a whole.

The armed aggression of the Russian Federation has led to an increase in the number of persons with physical and mental health impairments, creating barriers to education and professional realization. Large-scale destruction and occupation of territories have also caused mass internal displacement and the need for retraining.

At present, state and civic initiatives aimed at the adaptation of persons affected by war place particular responsibility on higher education institutions. The tasks of professional retraining, psychological support, and the promotion of the population's economic activity are coming to the forefront. Accordingly, the principles of inclusion should be integrated into the general strategy for the development of higher education, on an equal basis with academic standards and international cooperation.

On the basis of the theoretical analysis of the problem under study and our own experience of working in a higher education institution, we identified the key components of social inclusion in education:

1. Architectural accessibility, including barrier-free access to academic buildings, dormitories, libraries, and the arrangement of classrooms, such as adjustable desks and sound absorption.
2. Academic adaptation, including the provision of materials in different formats, such as text, audio, and video, individual educational plans, flexible deadlines for assignments, and the use of assistive technologies, including screen readers and speech-to-text software.
3. Socio-psychological integration, including work with teachers to overcome stereotypes, peer tutoring and mentoring programs, and the creation of an inclusive community in which diversity is perceived as a value.

These components require more detailed consideration.

Architectural accessibility is the creation of a physical environment in educational institutions that enables every higher education learner, regardless of physical ability, to move freely and use the premises and services (Dzhurylo, 2026). It is the foundation of inclusive education, as it guarantees equal access to educational services.

The main components of architectural accessibility include the following:

1. Accessible entrance: the presence of at least one entrance adapted for persons with reduced mobility, including the absence of thresholds and sufficient door width.

2. Ramps and lifts: the installation of standard-compliant ramps with an appropriate slope, or elevators and platform lifts providing access to upper floors.
3. Interior space: widened doorways, obstacle-free corridors, and accessible common areas, including libraries, canteens, and assembly halls.
4. Sanitary facilities: specially equipped toilets with grab bars and sufficient space for a wheelchair.
5. Navigation and marking: the use of tactile signs, including Braille, contrasting stair markings, and audio signals for persons with visual or hearing impairments.

The main principles for implementing architectural accessibility in inclusive education are universal design, reasonable accommodation, and barrier-free access. Universal design means creating a space that is convenient for all users from the outset, without the need for additional adaptation. Reasonable accommodation refers to specific changes and modifications made to ensure the rights of an individual with a disability when universal design does not fully address a particular need. Barrier-free access involves removing any physical or informational obstacles on the path to learning.

The creation of an architecturally accessible environment not only fulfills the requirements of the Law of Ukraine "On Education," but also contributes to the socialization of learners with special educational needs by preventing their isolation.

Academic adaptation in inclusive education refers to changes in teaching methods and assessment approaches for learners with special educational needs, without simplifying the curriculum itself (Lytvynova et al., 2018). The main purpose of academic adaptation in inclusive education is to provide learners with equal access to knowledge while taking into account their individual characteristics, including vision, hearing, pace of work, attention span, and other factors.

The selection of assistive technologies is one of the first steps toward making learning in Ukrainian higher education institutions genuinely barrier-free (Nikolenko, 2024). These tools help compensate for certain functional limitations, allowing students to focus on the content rather than how they access it (table 1).

Table 1
Assistive Technologies in Inclusive Education

Category	Examples of tools	For whom they are important
Screen readers	NVDA, JAWS, or built-in VoiceOver. These tools convert on-screen text into speech or Braille.	Learners with visual impairments
Text input technologies	Voice typing, adaptive keyboards, and eye-tracking systems	Learners with motor impairments
Visual support	Screen magnifiers, high-contrast modes, and special fonts for persons with dyslexia, such as OpenDyslexic	Learners with partial vision loss or dyslexia
Hearing support	Automatic captioning systems, such as Live Caption, and FM systems that transmit sound directly to a hearing aid	Learners with hearing impairments

Source: developed by the authors.

In Ukraine, universities have already established special resource centers where students can use such devices. However, technologies are effective only when educational content, including PDF files and presentations, is properly prepared.

Artificial intelligence (AI) can also support learners with special needs in several ways. First, AI can support content transformation through multimodality. It can instantly convert a photograph of lecture notes into structured text or read aloud a complex article through text-to-speech tools, which is critically important for persons with visual impairments. Second, AI can simplify and structure information. For students with autism spectrum disorders or dyslexia, AI can help identify the main points in a large body of text and remove unnecessary “information noise.” Third, AI can generate descriptions, including alt text. Modern models can accurately depict what a textbook graph or diagram shows, making visual information accessible to all learners. Fourth, AI can support the personalization of pace. AI tutors allow learners to review material as many times as necessary without fear of judgment or pressure.

The main components of socio-psychological integration in higher education institutions should include support centers where psychologists assist learners with adaptation and help teachers master appropriate methods for working with diverse learners. The entire university community should follow the principles of inclusive "person-first" ethics, which hold that the person, rather than their diagnosis or status, comes first. This concerns how to communicate appropriately, how to offer help, whether to offer help without being requested, and which terms to avoid to avoid offense. Student volunteers should support their peers in everyday and academic matters, thereby contributing to the socialization of both parties.

Psychological centers for social inclusion in higher education institutions in Ukraine are specialized units that provide support to students with special educational needs and help create a barrier-free environment. Their activities are regulated by Resolution No. 635 of the Cabinet of Ministers of Ukraine, which defines the procedure for organizing inclusive education in higher education institutions. Such centers should include a practical psychologist responsible for psychological well-being and corrective work, as well as a social pedagogue who provides socio-pedagogical support and assistance with socialization.

The main functions of such centers should include the following (Nikolenko, 2024):

1. Psychological support: individual counseling, assistance with adaptation to the educational process, and career guidance.
2. Social integration: organization of activities aimed at including students in the sociocultural life of the university.
3. Needs monitoring: diagnosis of needs and development of individual support plans.
4. Methodological work: training teachers in methods of working with inclusive groups.

Summarizing the above, it can be stated that the most significant indicators of social inclusion in higher education institutions should include the formation of an inclusive and barrier-free educational environment; access to adapted didactic materials and technical aids for persons with special educational needs; the implementation of financial support mechanisms, such as grants, scholarships, and loans, for vulnerable categories of students; the creation of conditions for personalized educational plans that take into account the needs of each learner; the appointment of a person responsible for implementing inclusive practices; measures aimed at developing an inclusive culture and preventing bullying; active involvement of student self-government in promoting inclusive policy; the use of variable learning models, including distance, asynchronous, and hybrid learning; multimodal presentation of information that takes into account the diversity of the student body, including social and cultural diversity; the introduction of flexible methods for assessing learning outcomes; the integration of specialized digital technologies to support students with special educational needs; and the organization of psychological support for participants in the educational process.

Post-War Expansion of Reasonable Accommodation: Inclusive Safety, Veteran Support, and Digital Rights

In the Ukrainian wartime and post-war context, the concept of reasonable accommodation should be expanded to include a security component. Traditionally, reasonable accommodation in European legal practice is associated with architecture, curricula, assessment procedures, and access to learning resources. However, under conditions of war, the right to education cannot be separated from the right to safety. Therefore, inclusive safety should be considered as an integral component of the inclusive institutional development of higher education.

First, higher education institutions should ensure not only the formal availability of shelters, but also their accessibility for persons with different nosologies. This includes tactile navigation, visual alarm notifications for persons with hearing impairments, accessible routes to shelters, and specialized resting places for persons with musculoskeletal disorders. The absence of an inclusive shelter should be interpreted not only as an infrastructural deficit, but also as a failure to provide an educational service of proper quality.

Second, the post-war period requires specific mechanisms for protecting the rights of veteran learners and combatants returning to education. Academic reintegration should include the right to academic leave for mental health reasons, especially in cases of PTSD aggravation or the need for long-term psychological rehabilitation. It should also include flexible assessment methods based on the principles of Universal Design for Learning. For learners who have cognitive consequences of blast injuries, such as impaired concentration, memory, or attention, the possibility of choosing the form of assessment, whether written, oral, project-based, or presentation-based, should be considered not as a privilege but as a compensatory mechanism for ensuring equal opportunities.

Third, digital rights should be recognized as a separate area of inclusive policy. During the war, digitalization became a primary condition for the realization of the right to education for many learners. In the post-war period, this experience should be transformed into a legal standard. Educational content that does not meet accessibility requirements, including WCAG 2.1 and EN 301 549, may reproduce digital discrimination by excluding learners with visual, hearing, motor, or cognitive impairments from full participation in the educational process. Therefore, the status of a digital assistant should be legally defined. Such a specialist would support learners with severe visual or motor impairments in interacting with university electronic systems, learning platforms, digital libraries, and administrative services.

Fourth, the institutional model of post-war inclusion should include Veteran Hubs or Offices of Inclusive Support operating on the principle of a "single window." These units should coordinate social support, psychological assistance, legal counseling, academic adaptation, career navigation, and communication with external partners. Their work should also include support for the right to the first workplace through cooperation with employers, quota-based mechanisms, or incentives for university partners who employ veteran graduates or persons with disabilities.

Fifth, post-war reconstruction of higher education institutions should be guided by the principle of Build Back Better. Any national or international assistance aimed at restoring university infrastructure should pass through an "inclusive filter." This means that reconstructed academic buildings, dormitories, shelters, libraries, laboratories, and digital infrastructure should be assessed not only for physical restoration but also for accessibility and universal design. The participation of representatives of public organizations of persons with disabilities in commissions responsible for accepting reconstructed facilities into operation should become mandatory. In addition, an Accessibility Passport for each educational facility may serve as a practical instrument for documenting compliance with accessibility requirements and as a condition for obtaining or maintaining a license for educational activity in the post-war period.

Thus, the post-war expansion of reasonable accommodation transforms inclusion from a set of compensatory measures into a broader institutional obligation that covers safety, digital rights, veteran reintegration, psychological support, and accessible reconstruction. Under such conditions, inclusive-institutional development becomes not only a requirement of European integration but also a mechanism for restoring trust, dignity, and social participation within the Ukrainian academic community.

Conclusions

The study of the formation of inclusive institutional educational development in Ukraine's context of European integration yields several conceptual conclusions.

The analysis has shown a fundamental change in the regulatory paradigm of higher education. The current stage of its development is characterized by a transition from the medical model of disability to the social-institutional and rights-based model. Inclusion is no longer interpreted as an act of charity, isolated support, or the goodwill of a higher education institution. It is becoming a legal and institutional requirement in educational environments that they be accessible, flexible, adaptive, and responsive to the needs of every learner.

The harmonization of Ukrainian higher education with the European legal framework is becoming a strategic condition for its modernization. The analysis of the UN Convention on the Rights of Persons with Disabilities, Directive 2000/78/EC, Directive (EU) 2016/2102, Directive (EU) 2019/882, the Rome Communiqué, the ESG, and the National Strategy until 2029 shows that inclusiveness is becoming an imperative condition for the functioning of higher education institutions. The implementation of reasonable accommodation, universal design, the social dimension of higher education, and accessibility standards creates a legal roadmap for Ukraine's integration into the European Higher Education Area.

Digital accessibility has become a technical and administrative requirement. In distance and blended learning settings, digital inclusion cannot be reduced to the use of digital platforms. It requires access to websites, mobile applications, LMS platforms, electronic libraries, e-books, video materials, tests, and administrative digital services. Compliance with WCAG and EN 301 549 should be incorporated into the internal quality assurance systems of higher education institutions. In this regard, digital accessibility should be understood as a technical condition for participation, whereas digital inclusion should be considered a broader process that ensures learners' real involvement, autonomy, and support in the digital educational environment.

The study confirms that institutional responsibility and control mechanisms in the field of inclusion have been strengthened. Inclusiveness has become a determinant of the legitimacy of educational activity through accreditation procedures, quality assurance standards, and compliance with the State Building Standards of Ukraine. The combination of NAQA accreditation requirements and technical regulation creates a double framework of responsibility for higher education institutions: academic responsibility for inclusive educational resources and administrative responsibility for the accessibility and safety of physical infrastructure.

The analysis of European support models demonstrates the need to move away from institutionalized, average-based funding toward more personalized financial mechanisms. The British Disabled Students' Allowance and the Polish disability-grant model show that support becomes more effective when it is linked either to the individual needs of the learner or to targeted institutional incentives. For Ukraine, the further development of inclusive higher education requires a gradual transition toward the principle that funding follows the learner, together with the legal recognition of assistants, digital support specialists, and personalized support services.

The post-war development of Ukrainian higher education requires expanding the concept of reasonable accommodation. Under wartime and post-war conditions, reasonable accommodation should include not only architectural accessibility, academic adaptation, and flexible assessment, but also inclusive safety, accessible shelters, veteran reintegration, academic leave for mental health reasons, assistive digital support, and trauma-informed educational practices. Veteran Hubs or Offices of Inclusive Support may serve as institutional mechanisms for coordinating psychological, legal, academic, and career-related support for learners affected by war.

Post-war reconstruction should be guided by the principle of Build Back Better and by the requirement of an inclusive filter for all restored educational infrastructure. Accessibility should be considered not as an additional option after reconstruction, but as a mandatory condition of educational quality, licensing, and public accountability. The introduction of Accessibility Passports for educational facilities and the involvement of representatives of organizations of persons with disabilities in the evaluation of reconstructed buildings would strengthen the practical implementation of universal design.

Thus, the formation of an inclusive institutional model of higher education in Ukraine is an irreversible process that requires synergy among legal norms, institutional responsibility, financial mechanisms, digital standards, safety requirements, and psychosocial support. In the context of European integration and post-war recovery, inclusion becomes not only an educational priority but also a criterion of the democratic, human-centered, and socially responsible development of Ukrainian higher education. The right to education can be considered fully realized only when barriers are not merely declared, but systematically identified, removed, and prevented through coordinated legal, organizational, technological, and pedagogical mechanisms.

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Chapter 2.
PARTNERSHIP INTERACTION IN A MODERN GYMNASIUM: ORGANIZATIONAL AND PEDAGOGICAL CONDITIONS AND ADAPTIVE EDUCATIONAL PRACTICES

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Abstract. *The chapter examines the organizational and pedagogical foundations of partnership interaction in modern Ukrainian gymnasiums under conditions of educational transformation, digitalization, and contemporary social challenges. Particular attention is paid to the implementation of partnership pedagogy as a conceptual basis for building a safe, adaptive, and learner-centered educational environment.*

The purpose of the study is to substantiate the organizational and pedagogical conditions that ensure effective partnership interaction among participants in the educational process and to determine the role of adaptive educational practices in strengthening the resilience of educational institutions.

The methodological framework of the study is based on theoretical analysis, synthesis, and generalization of scholarly literature, a systems approach, pedagogical modeling, and the interpretation of contemporary concepts of educational management. The findings identify seven interrelated organizational and pedagogical conditions for the effective implementation of partnership pedagogy in gymnasiums: professional development of teachers, participatory governance, transition to a matrix management model, collaborative programming of educational activities, development of innovation-oriented practices, strengthening cooperation among internal and external stakeholders, and systematic monitoring of partnership effectiveness.

The study demonstrates that adaptive educational practices, including blended learning, personalized educational trajectories, digital interaction, psychological support mechanisms, and inclusive approaches, contribute to the flexibility and sustainability of educational environments. It is argued that integrating organizational and pedagogical conditions with adaptive practices promotes

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educational resilience, strengthens participants' trust in the educational process, and supports the sustainable development of gymnasiums in times of uncertainty and social transformation.

***Keywords**: partnership pedagogy; partnership interaction; gymnasium; organizational and pedagogical conditions; adaptive educational practices; participatory governance; educational environment; educational resilience; educational adaptability; quality of education.*

Introduction

The modern system of general secondary education in Ukraine functions under conditions of large-scale social transformations caused by digitalization, educational reform, martial law, social instability, and the need to ensure the continuity of the educational process. Under such conditions, partnership pedagogy becomes especially relevant as a basis for creating a safe, inclusive, and adaptive educational environment.

The Concept of the New Ukrainian School defines partnership pedagogy as one of the central principles of organizing the educational process. Its essence lies in building effective interaction among teachers, learners, parents, and social partners.

The issue of partnership interaction becomes particularly relevant under conditions of crisis instability. Educational losses, the psychological vulnerability of participants in the educational process, the forced displacement of children, unequal access to digital resources, and blended learning formats require new approaches to organizing the activities of a gymnasium. It has been substantiated that the combination of organizational and pedagogical conditions with adaptive educational practices contributes to the formation of educational resilience in an educational institution and ensures its capacity to function effectively under conditions of uncertainty and social change.

The purpose of the study is to provide scientific and methodological substantiation of the organizational and pedagogical conditions for learning in a gymnasium, based on the partnership among participants in the educational process.

The methodological basis of the study includes theoretical analysis, comparative analysis of scholarly sources, a systems approach, the method of generalizing scientific provisions, and forecasting the development of the educational environment.

Educational transformations in the current realities have not merely expanded the functions of the school. They have also created a need for the qualitative organization of partnership interaction among participants in the educational process under wartime conditions. Contemporary leaders of educational institutions must lead a transformation of the gymnasium that ensures a safe, adaptable educational environment and creates a comfortable, trusting space.

A leading task today is the scientific and methodological substantiation and creation of organizational and pedagogical conditions that make partnership interaction the most effective and productive instrument of educational activity. The implementation of the principles of partnership pedagogy requires a transition from traditional methods to purposeful modeling that ensures the integrity and systematic character of the educational process in general secondary education institutions.

The analysis of managerial experience and mechanisms for determining organizational and pedagogical conditions for addressing contemporary tasks faced by general secondary education institutions leads us to conclude that administrators often make operational rather than planned decisions. They are determined by specific conditions or situations that are constantly changing. The analysis of contemporary scholarly approaches enables consideration of organizational and pedagogical conditions as a complex of interrelated managerial, methodological, psychological, and resource-based factors that ensure the effectiveness of the educational process and the achievement of a defined educational goal. In contemporary pedagogical discourse, such conditions are considered not merely as a set of external circumstances, but as an integrated system of organizing the educational environment that can influence the quality of interaction among participants in the educational process.

Within the framework of partnership pedagogy, organizational and pedagogical conditions should ensure openness of communication, coordination of interaction among the subjects of the educational process, flexibility of managerial decisions, and adaptability of the educational environment to contemporary challenges.

The management system of an educational institution is implemented at three levels: institutional, managerial, and technical. The institutional level determines how the educational institution interacts with the external environment and social partners. The managerial level ensures coordination among the administration, teachers, learners, and parents. The technical level is aimed at implementing the defined organizational and pedagogical conditions and ensuring the functioning of the educational environment.

Under conditions of crisis instability, managerial decisions must ensure psychological safety, digital accessibility, and continuity of the educational process. The digitalization of the educational process has significantly transformed the forms of interaction among participants. The use of digital technologies enables the continuity of learning, maintains operational communication, and creates additional opportunities for partnership interaction.

In a modern gymnasium, digital communication performs not only an informational function, but also a coordinating one. Electronic platforms, distance learning systems, online consultations, and digital educational resources ensure continuous communication among the administration, teachers, learners, and parents.

Digital interaction becomes especially important in blended or distance learning. Digital tools enable rapid adaptation of the educational process to crisis conditions, support individual educational trajectories, and provide access to learning materials. At the same time, the digitalization of the educational environment brings the problem of digital inequality to the forefront. Some learners may have limited access to technical devices or an unstable Internet connection. Therefore, an important task for an educational institution is to ensure variability in digital interactions and support the accessibility of the educational process.

As a result of the study, the following organizational and pedagogical conditions for implementing partnership interaction in a modern gymnasium were identified:

1. formation and implementation of a system for the training and retraining of pedagogical staff;
2. introduction of participatory governance;
3. transition to a matrix management model;
4. collaborative programming of activities;
5. development of innovative activity;
6. development of interaction between internal and external partners;
7. monitoring and evaluation of the effectiveness of partnership interaction.

These conditions form a coherent system rather than a simple list of organizational measures. The professional development of teachers creates the human and competence-based foundation for partnership interaction. Participatory governance provides mechanisms for involving teachers, learners, parents, and other stakeholders in decision-making. The matrix management model ensures organizational flexibility and enables the rapid formation of interdisciplinary, project-based teams. Collaborative programming of activities creates a shared strategic vision and strengthens collective responsibility for the gymnasium's development. Innovation-oriented activities provide tools for renewing educational content, methods, digital interactions, and forms of cooperation. The development of interaction between internal and external partners expands the educational institution's resource base and connects the gymnasium with the wider social environment. Monitoring and evaluation, in turn, provide feedback, enable the identification of risks and deficits, and support the timely correction of managerial and pedagogical decisions. Thus, the effectiveness of partnership pedagogy depends not on the isolated implementation of individual conditions, but on their systemic interaction.

Each of these conditions will be considered in more detail below.

Partnership pedagogy in a modern gymnasium should be understood not only as a value-based orientation toward cooperation but also as an organizational mechanism that enables an educational institution to remain functional, flexible, and socially responsive amid instability. In this sense, partnership interaction connects three interrelated dimensions of institutional development. The first is the managerial dimension, which concerns participatory decision-making, distributed responsibility, transparency of communication, and the involvement of internal and external stakeholders in the development of the educational institution. The second is the pedagogical dimension, which concerns the personalization of learning, the use of adaptive educational practices, support for diverse educational trajectories, and the creation of conditions for the active participation of every learner. The third is the socio-psychological dimension, which concerns trust, psychological safety, emotional support, and the educational community's ability to maintain cohesion during crises. The interaction of these dimensions transforms partnership from a declarative principle into a practical condition for educational resilience. Therefore, the organizational and pedagogical conditions identified in this study should be considered not as separate measures, but as elements of an integrated system that supports the sustainable development of a modern gymnasium.

1. Professional Development of Teachers in the Context of Partnership Pedagogy

The first organizational and pedagogical condition is the establishment of a professional development system for pedagogical staff. The effective implementation of partnership pedagogy requires the development not only of teachers' subject-matter competence but also of communication, facilitation, digital interaction, and crisis-response skills.

In contemporary educational discourse, teachers' professional development is considered a continuous process of developing professional competencies throughout one's career. The concept of lifelong learning involves continuous knowledge updating, the development of new professional roles, and readiness to work in conditions of rapid social change. Under such conditions, professional development ceases to be merely an instrument of advanced training and becomes a strategic resource for an educational institution's development.

The formation of competences necessary for implementing partnership pedagogy becomes especially important. A contemporary teacher increasingly acts not only as a source of knowledge but also as a facilitator of the educational process, a consultant, a mentor, and an organizer of interaction among all participants. This requires the development of effective communication skills, dialogue, conflict resolution, teamwork, and the ability to build trusting relationships with learners and their parents. An important component of professional development is the formation of teachers' digital competence. Contemporary educational practices increasingly integrate digital technologies into the educational process, requiring pedagogical staff to use electronic educational resources, digital platforms, distance learning services, and online communication tools. Digital competence becomes a necessary condition for supporting partnership interaction in blended or distance learning and for ensuring the continuity of the educational process.

Contemporary challenges also actualize the need to develop teachers' crisis competence. Martial law, forced displacement of the population, psychological traumatization of children, and educational losses require teachers to be able to work under conditions of uncertainty, support learners' psychological well-being, and create a safe educational environment. In this regard, important areas of professional development include mastering social and emotional learning technologies, the basics of psychological support, and crisis communication skills.

Professional Learning Communities have significant potential for teachers' development and are currently regarded as one of the most effective models of professional learning. Within such communities, teachers exchange experience, analyze their own practice, jointly develop educational solutions, and form a culture of collegial support. Such forms of interaction contribute to the development of a reflective culture within the teaching staff and strengthen partnership relations within the educational institution.

Teachers' professional development may be implemented through in-school training, training sessions, workshops, professional communities, internships, and the exchange of practical experience. The effectiveness of these forms is determined by their systematic character, practical orientation, and correspondence to the current needs of the teaching staff.

Thus, teachers' professional development serves as a basic organizational and pedagogical condition for the implementation of partnership pedagogy. The quality of partnership interaction and the effectiveness of a modern gymnasium largely depend on the level of development of professional, communicative, digital, and facilitation competences among pedagogical staff.

2. Participatory Governance as a Mechanism for Developing Partnership Interaction

The second organizational and pedagogical condition is the creation of organizational structures that function on the basis of participatory governance. This approach involves teachers in decision-making, strategic planning, and shaping the educational environment.

In contemporary educational management theory, participatory governance is considered one of the main mechanisms for democratizing the activity of an educational institution. Its essence lies in creating conditions for the active participation of all in the educational process in discussions and the adoption of managerial decisions. Unlike traditional administrative models based on a vertical distribution of authority, the participatory approach is oriented toward fostering participation, collegiality, and shared responsibility.

One of the main characteristics of contemporary partnership-based management is the concept of distributed leadership. This approach involves delegating part of managerial functions to pedagogical staff in accordance with their professional experience, competencies, and readiness to participate in the development of the educational institution. As a result, teachers act not only as implementers of managerial decisions but also as active participants in strategic planning and innovation processes.

An important element of participatory governance is the involvement of learners in management activities. Contemporary partnership pedagogy considers learners as full-fledged subjects of the educational process, capable of participating in decisions about the organization of school life. The activities of student self-government bodies, participation in civic initiatives, and involvement in educational projects contribute to the development of responsibility, civic engagement, and leadership qualities. The involvement of the parent community in the management processes of the educational institution is no less important. Within the partnership approach, parents are viewed not only as recipients of information about children's learning outcomes but also as active participants in shaping the institution's educational policy. Their participation in advisory bodies, strategic sessions, public discussions, and joint educational projects strengthens trust between school and family.

Participatory governance becomes especially important under conditions of crisis challenges. Martial law, changes in learning formats, and the need to respond rapidly to participants' new needs in the educational process require a high level of flexibility in the management system. Collegial decision-making enables consideration of diverse perspectives, mobilizes the resources of the educational community, and enhances the quality of managerial decisions.

At the same time, the effectiveness of participatory governance largely depends on the level of organizational culture in the educational institution. Open communication, mutual trust, readiness for cooperation, and respect for the diversity of opinions create the necessary prerequisites for the functioning of a partnership-based model of management.

Thus, participatory governance serves as an important mechanism for developing partnership interaction in a modern gymnasium. It ensures all participants' involvement in the educational process in decision-making, fosters responsibility and initiative, enhances the educational institution's adaptability, and creates conditions for the formation of a sustainable partnership culture.

3. Transition to a Matrix Management Model of the Gymnasium

The third organizational and pedagogical condition is the transition to a matrix management model of the gymnasium. The matrix model ensures the combination of vertical managerial links with horizontal interaction among the structural units of the educational institution.

This approach enables the implementation of several educational strategies simultaneously, the coordination of innovative activities, and flexibility in managerial decisions. Under conditions of crisis instability, the matrix model enhances the management system's adaptability and supports effective coordination of partnership interactions.

In the current context of general secondary education institutions, the matrix management model is viewed not only as an instrument of organizational modernization but also as a mechanism for ensuring flexibility, adaptability, and effective coordination among all participants in the educational process. The relevance of its implementation is determined by the high dynamics of change in education driven by digital transformation, educational reform, inclusive learning, strengthened institutional autonomy, and the need for rapid responses to wartime challenges.

Traditional hierarchical management models, based on vertical subordination, are not always able to ensure the required level of promptness in managerial decision-making. Under such conditions, there is a need for organizational structures that combine the clarity of the managerial vertical with the possibility of horizontal interaction among all subjects of educational activity. The matrix management model is precisely such a structure.

Matrix management involves the simultaneous functioning of several interconnected managerial dimensions, within which pedagogical staff may participate in both fulfilling their direct professional duties and the work of temporary or permanent project groups. This approach ensures a high level of mobility within the educational system, promotes teachers’ professional initiative, and lays the groundwork for the effective implementation of the principles of partnership pedagogy.

A distinctive feature of the matrix model is the combination of functional and project-based management. Within the functional dimension, the stability of the educational process, the implementation of educational programs, compliance with regulatory requirements, and the organization of the institution's daily activities are ensured. At the same time, the project-based dimension enables the formation of temporary creative groups to implement specific educational tasks, innovation projects, development programs, or activities aimed at improving the quality of the educational environment.

Within the framework of partnership pedagogy, the matrix model is particularly important because it provides opportunities for a wide range of participants to engage in educational interactions in the decision-making process. Teachers can participate in the development of educational strategies, the planning of innovation activities, the creation of new educational products, and the formulation of managerial decisions. As a result, there is a gradual transition from a control-based management model to one based on trust, cooperation, and shared responsibility.

A significant advantage of the matrix structure is the ability to rapidly form interdisciplinary teams to solve urgent educational problems. For example, when organizing an inclusive educational environment, a working group may include the institution's administration, subject teachers, a practical psychologist, a social pedagogue, a teacher assistant, and representatives of the parent community. Such interaction ensures a comprehensive approach to solving the problem and allows for the needs of all participants in the educational process to be taken into account.

The role of the matrix model under conditions of crisis instability is no less important. Martial law, forced displacement of participants in the educational process, the need to switch rapidly between different learning formats, and the need for psychological support for children and teachers require a high level of adaptability of the management system. Matrix management enables the creation of crisis teams quickly, the identification of responsible persons for specific areas of work, coordination among structural units, and the maintenance of the continuity of the educational process even under difficult conditions.

In contemporary European educational practice, approaches based on the principles of distributed leadership are becoming increasingly widespread. This concept involves moving away from the exclusive concentration of managerial functions in the hands of the administration and gradually delegating them to pedagogical staff based on their competence, professional experience, and readiness to take responsibility for decision-making. It is the matrix model that creates the most favorable conditions for implementing the principles of distributed leadership and developing teachers' professional autonomy.

The effectiveness of the matrix structure largely depends on the educational institution's organizational culture. Partnership interaction is impossible under conditions of authoritarian approaches, restrictions on professional initiative, or the absence of open communication. Therefore, implementing the matrix model should be accompanied by an atmosphere of mutual trust, support, and constructive dialogue among all participants in the educational process. Digital management tools are an important element of the matrix model's functioning. The use of electronic platforms, shared information environments, digital calendars, planning systems, and monitoring systems enables effective coordination of project groups, rapid information exchange, and transparent management processes.

Digitalization significantly expands the possibilities of horizontal interaction and creates conditions for involving all educational partners in joint activity, regardless of their location.

Thus, the matrix management model serves not only as an organizational mechanism for implementing partnership pedagogy but also as an important instrument for developing a modern, adaptive gymnasium. Its implementation contributes to increasing the effectiveness of managerial activity, developing teachers' professional autonomy, strengthening partnership relations among participants in the educational process, and ensuring the resilience of the educational institution amid constant social change.

4. Collaborative Programming of Activities

The fourth condition is the collaborative programming of future activities in accordance with the newly selected strategy. This approach contributes to the formation of a shared vision for the educational institution's development, enhances professional responsibility, and supports a culture of partnership. In contemporary pedagogical science, collaborative programming of activities is regarded as one of the most effective mechanisms for implementing the principles of partnership interaction in the educational environment. Unlike the traditional approach, in which strategic decisions are mainly made by the educational institution's administration, collaborative programming involves all participants in the educational process in planning. They are given the opportunity to influence the identification of institutional development priorities, the content of educational activities, and the ways of achieving jointly defined goals. The need to move toward collaborative programming of activities is primarily determined by a change in the philosophy of modern education. The educational environment is no longer viewed as a space of one-sided managerial influence. It is understood as an open socio-pedagogical system whose successful functioning depends on each participant's level of involvement and responsibility. For this reason, contemporary approaches to educational management are increasingly based on the principles of participation, democratic governance, and distributed leadership.

Collaborative programming of activities creates conditions for forming a shared vision of the future of the educational institution. Practice shows that the most successful educational institutions are those in which the teaching staff, learners, parents, and community representatives are not only informed about strategic development goals, but also directly participate in their definition. Under such conditions, the educational strategy ceases to be exclusively an administrative document and becomes the result of collective creative activity.

An important component of collaborative programming is strategic planning. In modern educational institutions, it may be implemented through strategic sessions, roundtables, new-type pedagogical councils, facilitation meetings, and working groups. Unlike traditional forms of discussion, such activities involve the active participation of all stakeholders in developing joint decisions, analyzing problems, and identifying promising directions for development.

Collaborative programming becomes especially relevant under conditions of social instability. Martial law, demographic changes, the digitalization of education, and the emergence of new educational needs and challenges require a high level of flexibility and rapid adaptability. Under such conditions, effective planning is impossible without taking into account different perspectives, teachers' professional experience, learners' needs, and the expectations of the parent community.

One of the main outcomes of collaborative programming is the formation of shared responsibility for achieving the defined goals. When decisions are made collectively, participants' motivation to implement them increases, the sense of involvement in a common cause is strengthened, and trust within the collective grows. As a result, prerequisites are created for the formation of a sustainable partnership culture, which gradually becomes an important characteristic of the educational environment.

At the same time, collaborative programming does not mean abandoning the administration's managerial role. On the contrary, the head of the educational institution serves as the coordinator and facilitator of the joint activity. Their task is not only to organize the discussion process, but also to create conditions in which every participant in the educational process can express their own position, propose ideas, and take part in developing joint decisions.

Digital technologies serve as an important instrument for implementing collaborative programming. The use of electronic platforms for joint planning, online surveys, digital boards, cloud services, and project management systems enables significantly greater participation by participants in the educational process in managerial activities. Such tools become especially important during periods of distance or blended learning, when traditional forms of interaction may be limited.

Another important component of collaborative programming is orientation toward forecasting future changes. In contemporary educational practice, foresight technologies are becoming increasingly widespread. They enable modeling potential scenarios for the development of an educational institution, assessing potential risks, and identifying promising directions of activity. The use of foresight planning elements increases an educational institution's strategic readiness for future challenges and supports its long-term competitiveness.

Thus, collaborative programming of activities functions not only as an organizational and pedagogical condition for the implementation of partnership pedagogy, but also as an important instrument for forming a contemporary culture of educational management. It ensures the involvement of all participants in the educational process in the development of strategic decisions, promotes partnership relations, increases responsibility, and creates conditions for the sustainable development of a gymnasium amid constant social change. The analysis indicates that the formation of a partnership culture primarily occurs within the teaching staff, where mechanisms of cooperation, communication, and collegial decision-making are developed. The implementation of the principles of partnership pedagogy in interaction with learners is impossible without their prior establishment in the professional culture of the teaching staff. It is the internal cooperation of teachers, joint planning of activities, collegial discussion of managerial decisions, and mutual support that create the foundation for extending partnership practices to all levels of educational interaction.

5. Innovation-Oriented Activity as a Mechanism for Developing a Partnership Educational Environment

Innovation-oriented activity becomes particularly important under conditions of dynamic social change. A modern gymnasium operates in an environment characterized by rapid information renewal, the development of digital technologies, changes in learners' educational needs, and increasing demands for the quality of educational services. Under such conditions, the capacity for innovation becomes an important prerequisite for an educational institution's competitiveness and successful adaptation to new challenges.

Innovation-oriented activity in a gymnasium is comprehensive and covers various areas of educational environment development. First of all, it involves implementing contemporary pedagogical technologies that foster learners' active participation in the educational process. Within the framework of partnership pedagogy, particular importance is attached to project-based learning, research activity, blended learning, collaborative learning, the case method, problem-based learning, and technologies for developing critical thinking. Their use enables active interaction between teachers and learners, develops learners' subject positions, and fosters teamwork skills.

At the same time, contemporary innovations are not limited exclusively to pedagogical technologies. Organizational innovations aimed at improving the management system of an educational institution have considerable potential to develop partnership interactions. Such innovations include the creation of professional learning communities, the development of internal centers for professional growth, the formation of interdisciplinary creative groups, the organization of pedagogical hubs, and the introduction of network-based forms of cooperation among educational institutions. These activities foster horizontal connections and contribute to the formation of a culture of professional partnership.

Digital transformation of the educational environment plays a separate role in the process of innovative development. In contemporary conditions, digital technologies are becoming not only a means of supporting the educational process but also an important factor in developing new models of interaction among all participants. The use of digital platforms, electronic journals, educational applications, interactive resources, and cloud services creates additional opportunities for cooperation, joint planning of activities, and rapid information exchange. Particular attention should be paid to developing the teaching staff's digital culture. Practice shows that the effectiveness of digitalization largely depends not on the technical equipment of the educational institution, but on teachers' readiness to use digital tools in their professional activity. Therefore, an important component of innovative development is the formation of pedagogical staff's digital competence, the development of skills in using modern educational platforms, and the creation of conditions for continuous professional learning.

Innovation-oriented activity is also directly related to the development of an inclusive educational environment. A modern gymnasium must ensure equal access to quality education for all categories of learners, regardless of their individual characteristics, educational needs, or social status. In this regard, innovative practices enable the educational process to adapt to the needs of different groups of learners, ensure differentiated learning, and create conditions for the fullest possible realization of each child's potential.

The development of the project culture of an educational institution is another important direction of innovation-oriented activity. Contemporary educational projects increasingly go beyond the boundaries of a single educational institution and are implemented in cooperation with local self-government bodies, higher education institutions, public organizations, and international partners. Participation in such projects expands educational opportunities for learners and teachers, attracts additional resources, and contributes to the formation of an open educational environment.

It should be emphasized that innovation-oriented activity cannot be considered as a set of separate events or short-term initiatives. Its effectiveness is determined by its systematic character, consistency, and integration into the educational institution's overall development strategy. Only under such conditions do innovations become not temporary changes but a sustainable mechanism for developing the educational environment and improving its quality.

Thus, innovation-oriented activity serves as an important instrument for implementing partnership pedagogy and ensuring the sustainable development of a modern gymnasium. It contributes to the renewal of educational content, the development of teachers' professional culture, the improvement of managerial mechanisms, and the creation of conditions for effective interaction among all participants in the educational process. It is the innovative orientation of the educational institution's activity that creates the prerequisites for its successful functioning under conditions of constant social change and for the formation of a competitive educational environment.

6. Development of Interaction between Internal and External Partners

Innovation-oriented activity in a modern gymnasium is impossible without expanding the range of actors involved in the educational process. Whereas the traditional school functioned for a long time mainly as a relatively closed system, within which the main interaction took place among the administration, teachers, and learners, the modern gymnasium is increasingly acquiring the features of an open socio-pedagogical system. Under such conditions, the development of interaction between the internal and external partners of the educational institution is an important organizational and pedagogical condition for implementing partnership pedagogy.

Contemporary scholarly approaches to educational management consider a general secondary education institution as a complex multilevel system of social relationships, the effectiveness of which largely depends on the quality of communication among all stakeholders. The educational process is no longer limited exclusively to the activities of teachers and learners. It involves the active engagement of the parent community, local self-government bodies, public organizations, higher education institutions, employers, international partners, and other actors in educational activity.

Within the framework of partnership pedagogy, the concept of educational partnership is particularly important as a form of voluntary, mutually beneficial cooperation aimed at achieving shared educational goals. Unlike traditional interaction, which was often limited to information exchange or episodic activities, partnership involves long-term cooperation, joint planning, distribution of responsibilities, and the collective achievement of results.

Pedagogical staff play a primary role among internal partners. The effectiveness of implementing the institution's educational policy largely depends on the level of its professional interaction. In a modern gymnasium, professional cooperation increasingly goes beyond subject departments or methodological associations. Interdisciplinary teams, creative groups, and professional communities are forming to work on joint educational projects, develop curricula, implement innovative practices, and address current educational problems.

Learners are no less important participants in partnership interaction. Contemporary approaches to organizing the educational process entail a gradual transition from the object position to the learner's subject position. This means that learners not only participate in learning but also become active participants in decision-making related to the development of the educational environment. Involving learners in student self-government bodies, project teams, civic initiatives, and volunteer activities contributes to the development of responsibility, leadership qualities, and social interaction skills.

The role of the parent community also requires special reconsideration in contemporary conditions. The Concept of the New Ukrainian School defines parents not as external observers of the educational process, but as equal partners of the educational institution. At the same time, an effective partnership between school and family requires a transition from formal information to genuine dialogue, grounded in mutual trust, respect, and shared responsibility for the learning and upbringing of children.

In contemporary practice, various forms of parental cooperation are becoming increasingly widespread. These include advisory councils, joint educational projects, thematic forums, strategic sessions, public discussions, and digital platforms for continuous communication. Such forms of interaction make it possible not only to increase parents' level of awareness, but also to involve them in exerting real influence on the development of the educational environment.

External partnerships have significant potential for developing a gymnasium. One of the most promising areas is cooperation with higher education institutions. Such a partnership creates opportunities for teachers' professional development, learners' involvement in research activity, the implementation of joint educational programs, and participation in academic events.

At the same time, universities gain opportunities to test innovative pedagogical developments and expand the practical component of future teachers' training.

Interaction with territorial communities and local self-government bodies also occupies an important place. Under contemporary conditions, the community increasingly participates actively in the development of the educational institution. The joint implementation of educational, cultural, environmental, and social projects strengthens links between the school and the local community, increases the social significance of educational activity, and broadens opportunities to attract additional resources.

Cooperation with public organizations and international institutions deserves separate attention. Participation in international educational programs, grant projects, and professional networks allows the educational institution to integrate into the international educational space, gain access to contemporary educational practices, and expand opportunities for the professional development of teachers and learners. Such partnerships have become especially relevant under wartime conditions, when international support is crucial to ensuring the resilience of Ukrainian education.

The development of partnership interaction also involves establishing an effective communication system among all participants in the educational process. Openness of information, transparency of managerial decisions, regular feedback, and the possibility of participating in discussions of current issues create prerequisites for strengthening trust and fostering a positive socio-psychological climate in the educational environment.

Thus, the development of interaction between internal and external partners is an important organizational and pedagogical condition for implementing partnership pedagogy in a modern gymnasium. It is the expansion of partnership ties that enables ensuring the openness of the educational environment, mobilizing additional development resources, strengthening the social significance of education, and creating conditions for the sustainable development of the educational institution amid social transformation.

7. Monitoring and Evaluation of the Effectiveness of Partnership Interaction

The seventh organizational and pedagogical condition is monitoring and evaluation of the effectiveness of partnership interaction. In contemporary educational management theory, monitoring is a continuous process of collecting, analyzing, interpreting, and using information to make evidence-based managerial decisions. Unlike traditional control, which mainly records the final outcome of an activity, monitoring is oriented toward continuous process tracking and the identification of development trends. Therefore, it is an important instrument for ensuring the quality of educational activity and supporting the sustainable development of an educational institution.

An important indicator of the effectiveness of partnership interaction is the level of agency of participants in the educational process. The more actively learners, teachers, and parents participate in decision-making, the higher the level of development of partnership culture. For this reason, evaluating the degree of involvement in managerial and educational processes can be considered one of the main indicators of the effectiveness of implementing partnership pedagogy.

The evaluation of partnership interaction in a gymnasium should be based on a set of indicators that reflect not only formal participation, but also the real quality of cooperation among participants in the educational process. Such indicators may include the level of teachers’ involvement in collegial decision-making; the frequency and effectiveness of joint projects involving teachers, learners, parents, and external partners; the degree of learners’ participation in student self-government and project teams; the level of parental trust in the educational institution; the transparency of communication between the administration and the educational community; the accessibility of digital communication channels; the effectiveness of psychological support mechanisms; the stability of professional learning communities; and the extent to which monitoring results are used for further improvement of educational practice. These indicators enable assessing partnership interaction not only as a declared principle but also as an observable and manageable component of the educational environment.

Monitoring the educational environment becomes especially important under conditions of social instability and crisis challenges. Martial law, forced population migration, changes in learning formats, and increasing psychological pressure significantly affect the nature of interaction among participants in the educational process. Under such conditions, there is a need for regular assessment of the level of psychological safety in the educational environment, the emotional well-being of learners and teachers, and the effectiveness of the support mechanisms functioning within the educational institution.

A separate monitoring activity involves evaluating the professional development of pedagogical staff. The implementation of partnership pedagogy requires teachers to assume new professional roles, including those of facilitator, mentor, consultant, and coordinator of educational interaction. Therefore, it is important to track the dynamics of teachers' professional competence development, their readiness for teamwork, their use of innovative technologies, and their participation in professional communities.

The digitalization of education opens substantial opportunities to improve monitoring activities. Contemporary information and analytical systems enable automated data collection, rapid analysis, and visualization of evaluation results. The use of digital tools increases the objectivity of monitoring and creates conditions for more effectively using the results in managing the educational institution.

At the same time, the effectiveness of monitoring is determined not only by the quality of the collected information, but also by participants' readiness, during the educational process, to use evaluation results to improve their own activity. For this reason, contemporary approaches to evaluation increasingly emphasize the development of a culture of reflection and self-assessment. The ability of the teaching staff to critically analyze the results of their work and use the data obtained to plan future changes is an important feature of a mature organizational culture.

Thus, monitoring and evaluation of the effectiveness of partnership interaction is not the final stage in implementing organizational and pedagogical conditions, but a continuous mechanism for supporting their effectiveness. It is through the systematic analysis of the results of educational activity that the timely identification of problems, the adjustment of development directions, and the sustainable functioning of a modern gymnasium under conditions of constant social change become possible. The implementation of the identified organizational and pedagogical conditions lays a foundation for an adaptive and resilient educational environment capable of ensuring quality education amid social transformation and crisis challenges.

8. Adaptive Educational Practices as a Mechanism for Ensuring the Effectiveness of Partnership Interaction in a Modern Gymnasium

In contemporary pedagogical science, adaptability is increasingly recognized as a fundamental characteristic of an effective educational system. Rapid social change, the digitalization of all spheres of life, the consequences of the COVID-19 pandemic, wartime challenges, and large-scale migration have significantly altered the conditions under which educational institutions operate. Under such circumstances, the ability of the educational environment to respond promptly to new challenges becomes not only an indicator of its effectiveness but also a necessary prerequisite for ensuring the continuity of the educational process. For this reason, adaptive educational practices are currently considered an important mechanism for implementing partnership pedagogy and supporting the sustainable development of a gymnasium.

The concept of adaptability in education goes far beyond the ability to rapidly change the forms of organizing learning. In its contemporary understanding, an adaptive gymnasium is an open educational system capable of changing its content, forms, methods, and organizational mechanisms in accordance with the needs of participants in the educational process and external conditions. This capacity ensures the resilience of the educational environment and enables it to maintain effective functioning even under high levels of uncertainty.

Adaptability becomes especially important within the framework of partnership pedagogy. Partnership interaction involves taking into account the individual needs, capacities, and educational requests of all participants in the educational process. Accordingly, the educational environment must be sufficiently flexible to ensure individualized learning, support diverse educational trajectories, and create conditions for the full participation of every participant in the educational activity.

One of the most widespread adaptive practices in a modern gymnasium is blended learning. The combination of face-to-face and distance forms of organizing the educational process enables the continuity of learning regardless of external circumstances. At the same time, blended learning expands opportunities to individualize the educational process, develop learners' independence, and foster self-organizational skills. Such practices became especially relevant during the pandemic and under martial law, when educational institutions were forced to switch rapidly between different learning formats.

Personalization of the educational process is another important adaptive practice. A modern gymnasium is increasingly oriented toward taking learners' individual characteristics, educational needs, interests, and levels of preparation into account. The use of individual educational trajectories, differentiated tasks, adaptive digital resources, and formative assessment tools creates conditions for the fullest possible realization of each learner's potential.

Psychological support practices for participants in the educational process are becoming increasingly important in contemporary conditions. Hostilities, forced displacement, prolonged stress, and uncertainty negatively affect the psychological state of children, teachers, and parents. In this regard, an adaptive educational environment should ensure not only quality learning but also psychological safety. Such practices include socio-emotional learning programs, psychological support groups, counseling assistance, the development of stress-resilience skills, and the formation of a culture of psychological well-being.

Ensuring inclusiveness is an important component of adaptive educational practices. A modern gymnasium must create conditions for the full participation of all categories of learners in the educational process, regardless of their individual characteristics or educational needs. Adaptive approaches enable flexible changes to teaching methods, educational materials, and forms of interaction in accordance with the needs of specific participants in the educational process. As a result, an educational environment grounded in equality, accessibility, and respect for diversity is created.

Contemporary adaptive practices also involve the active use of digital technologies. Educational platforms, electronic resources, interactive services, and tools for learning analytics enable more flexible management of the educational process and prompt responses to changes in learners' educational needs. At the same time, digital technologies are not an end in themselves, but a means of expanding opportunities for partnership interaction and the individualization of learning.

Thus, adaptive educational practices serve as an important mechanism for implementing partnership pedagogy in a modern gymnasium. They ensure the flexibility of the educational environment, support its resilience to external challenges, and create conditions for the full participation of all subjects of the educational process in joint activity. It is the combination of organizational and pedagogical conditions with adaptive practices that forms the basis for the sustainable development of a modern gymnasium and for improving the quality of education under conditions of social transformation.

9. Educational Resilience of the Gymnasium as a Result of Implementing Partnership Pedagogy

In recent years, the concept of educational resilience has acquired particular relevance in international educational discourse. Whereas researchers previously focused mainly on the quality of education and the effectiveness of educational institution management, contemporary social challenges have created the need to rethink the capacity of educational systems to function under conditions of instability, uncertainty, and crisis. For this reason, alongside the concepts of effectiveness, innovation, and competitiveness, the category of educational resilience is increasingly used. It characterizes an educational system's capacity to maintain its functionality, adapt to change, and continue its development even under adverse conditions.

In the functioning of a modern gymnasium, educational resilience cannot be understood exclusively as the ability to maintain the educational process during crisis events. Its meaning is much broader and encompasses a set of organizational, pedagogical, socio-psychological, and managerial mechanisms that ensure the long-term stability of the institution’s development. In this sense, resilience functions as an integral characteristic of the educational environment, reflecting its readiness for change, capacity for self-development, and effective use of internal and external resources.

The issue of educational resilience becomes especially important under wartime conditions. Large-scale social upheavals, security risks, displacement of participants in the educational process, changes in learning formats, and increased psychological pressure create additional challenges for the functioning of educational institutions.

Under such conditions, a gymnasium's ability to maintain the quality of education, ensure psychological safety, and preserve partnership relations among participants in the educational process becomes a key indicator of its resilience.

The development of educational resilience is directly connected to the formation of partnership pedagogy. Partnership relations create an additional support resource that enables the mobilization of the potential of the teaching staff, learners, the parent community, and external partners to overcome crisis situations. The experience of Ukrainian educational institutions functioning under wartime conditions shows that the highest level of resilience is demonstrated by those institutions where a high level of trust, open communication, and collective responsibility has been formed.

Institutional flexibility is an important component of educational resilience. A modern gymnasium must be able to rapidly change the forms of organizing the educational process, adapt managerial mechanisms, and revise activity priorities in response to changes in external conditions. At the same time, such flexibility should not compromise strategic integrity. On the contrary, adaptability should be combined with a clear vision of the educational institution's long-term development goals.

The development of the social capital of the educational community is no less important for ensuring educational resilience. This refers to the set of trusting relationships, social ties, interaction norms, and shared values formed among all participants in the educational process. Social capital often serves as a resource that enables an educational institution to effectively overcome crisis situations and maintain a high level of collective cohesion.

Contemporary research also indicates the importance of participants' psychological resilience in the educational process. The psycho-emotional well-being of teachers and learners directly affects the quality of educational activity, motivation levels, and communication effectiveness. In this regard, practices of socio-emotional learning, psychological support, and the development of emotional self-regulation skills are becoming increasingly important.

At the same time, educational resilience is not a static state. It is constantly formed, supported, and developed through the interaction of all elements of the educational system. For this reason, the creation of mechanisms for continuous risk analysis, readiness assessment for change, and the improvement of organizational and pedagogical practices in response to new challenges becomes particularly important.

Thus, the educational resilience of a modern gymnasium results from the comprehensive implementation of organizational and pedagogical conditions, the development of partnership interactions, and the introduction of adaptive educational practices. It ensures the educational institution's capacity not only to preserve its functionality in crisis situations, but also to use these situations as a stimulus for further development and improvement of the educational environment.

Conclusions

The analysis of the theoretical foundations and practical mechanisms for organizing learning in a modern gymnasium has shown that partnership pedagogy today functions not only as one of the leading educational concepts but also as an important factor in ensuring the quality, adaptability, and resilience of the educational environment. The transformational processes taking place in the education system under the influence of globalization, digitalization, social change, and wartime challenges determine the need to move from traditional models of management and organization of the educational process to more flexible, open, and human-centered approaches based on mutual trust, cooperation, and shared responsibility.

The study established that the effective implementation of partnership pedagogy in a modern gymnasium requires the creation of an integrated system of organizational and pedagogical conditions, interconnected and forming a unified mechanism for developing the educational environment. A determining role in this process is played by the professional development of pedagogical staff, the introduction of participatory models of governance, the use of matrix organizational structures, collaborative programming of activities, the development of an innovative culture, the expansion of partnership ties, and the creation of a system for monitoring the effectiveness of educational activity. It is the interaction of these components that ensures the transition from the formal declaration of partnership relations to their real functioning in the everyday practice of the educational institution.

The findings support the argument that partnership pedagogy should be understood as a multidimensional mechanism that integrates managerial, pedagogical, and socio-psychological dimensions of institutional development. The managerial dimension is expressed through participatory decision-making, distributed responsibility, and transparent communication. The pedagogical dimension is reflected in personalization, adaptive educational practices, inclusive approaches, and support for different educational trajectories. The socio-psychological dimension concerns trust, psychological safety, emotional support, and the educational community's capacity to maintain cohesion under crisis conditions. The interaction of these dimensions transforms partnership pedagogy from a value-based principle into a practical condition for educational resilience.

The study confirmed that the modern gymnasium is increasingly acquiring the features of an open socio-pedagogical system, the development of which largely depends on the quality of communication and cooperation among all subjects of the educational process. Under such conditions, participants in educational interactions cease to be merely performers of assigned functions and gradually become active partners capable of influencing decision-making, shaping the institution's educational policy, and implementing shared strategic goals. This contributes to agency development, increases responsibility, and fosters a culture of participation aligned with contemporary international approaches to democratic governance in education.

Particular attention in the study was paid to adaptive educational practices as a mechanism for ensuring the effectiveness of partnership interaction. It was established that the adaptability of a modern gymnasium is manifested in its ability to respond promptly to changes in the external environment, take into account the individual needs of participants in the educational process, and ensure the continuity of educational activity under conditions of uncertainty. The use of blended learning, personalized educational trajectories, digital technologies, inclusive approaches, and psychological support practices creates additional opportunities to implement the principles of partnership and improve the quality of the educational process.

The study also found that, amid contemporary social challenges, the development of educational resilience in a gymnasium is especially important. Educational resilience is considered an integral characteristic of an educational institution that reflects its capacity to maintain effective functioning, adapt to change, and ensure further development even under adverse circumstances. Important factors in its formation include trust among participants in the educational process, the development of the educational community's social capital, effective communication, institutional flexibility, and readiness for innovative change.

The monitoring and evaluation of partnership interaction should be regarded as a continuous mechanism for supporting the quality of educational management rather than as a final stage of organizational activity. The effectiveness of partnership pedagogy can be assessed through indicators such as the level of participation of teachers, learners, and parents in decision-making; the quality of joint projects; the accessibility of digital communication; the effectiveness of psychological support; the stability of professional learning communities; and the use of monitoring results for the further improvement of educational practice. This makes partnership interaction not only a declared principle, but also an observable and manageable component of the educational environment.

Thus, partnership interaction in a modern gymnasium should be considered a complex, multidimensional process encompassing the managerial, pedagogical, social, and communicative aspects of an educational institution's activity. Its effectiveness is determined not by individual activities or forms of work, but by the integrity of the educational system, its capacity to ensure interaction among all participants in the educational process, and its ability to create conditions for their joint development. It is the combination of organizational and pedagogical conditions with adaptive educational practices that forms the foundation for the sustainable development of a modern gymnasium, the improvement of educational quality, and the strengthening of its role as an important social institution amid dynamic social transformation.

The presented system of organizational and pedagogical conditions and adaptive educational practices forms an integrated mechanism for implementing partnership pedagogy in a modern gymnasium. Their interaction ensures not only the improvement of the quality of the educational process, but also the development of the institution's educational resilience under conditions of social transformation and crisis challenges. In this regard, the modern gymnasium can be understood as an adaptive partnership-based educational environment in which shared responsibility, institutional flexibility, inclusive participation, and continuous reflection become prerequisites for sustainable development.

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Chapter 3.
THE CAPACITY OF PRE-SERVICE STEM TEACHERS FOR PERSONALIZED LEARNING IN INCLUSIVE EDUCATION UNDER UNSTABLE INTERNET ACCESS

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Abstract. *The chapter substantiates the capacity of pre-service STEM teachers to personalize learning as an integrated soft skill that combines methodological flexibility, inclusive sensitivity, digital-pedagogical maturity, emotional support, and readiness to act under conditions of unstable or absent Internet access. The problem is relevant because personalized learning in STEM education is often associated with digital platforms, adaptive systems, and artificial intelligence tools, whereas effective pedagogical practice requires maintaining individualized support even in contexts with limited digital infrastructure. Particular attention is paid to inclusive education, where personalization is a condition for the accessibility of mathematical, scientific, and technological content for learners with different learning capacities, work pace, cognitive characteristics, and special educational needs. The purpose of the study was to theoretically substantiate and empirically describe the capacity of pre-service STEM teachers to personalize learning in an inclusive, offline-oriented environment. The methodology combined the analysis of current scholarly sources and a pilot quasi-experimental study based on the design "pre-test – formative intervention – post-test." The study involved 38 future mathematics teachers who formed one pilot group. The dynamics of their capacity for personalizing learning were examined by comparing results before and after a short-term formative intervention. The results showed clear positive dynamics after the formative intervention: participants more often proposed specific offline adaptations, identified learning difficulties more accurately, varied explanations, adapted the pace, and used emotionally supportive communication. It has been demonstrated that offline conditions may function not only as a technical limitation, but also as a diagnostic environment that reveals the depth of pedagogical readiness for personalization. The practical significance of the results lies in the possibility of using the proposed approach in the methodological training of future STEM teachers.*

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Keywords: *personalization of learning; STEM education; future teachers; inclusive education; soft skills; offline learning; unstable Internet; differentiated instruction; digital competence; pedagogical diagnostics.*

Introduction

Personalization of learning has become one of the most visible trends in STEM education, as it directly addresses the need to consider learners' different learning capacities, the pace of mastery, prior experience, motivation, cognitive characteristics, and educational barriers. In STEM disciplines, this problem becomes especially evident. Mathematics, computer science, natural sciences, and technological disciplines rely on abstract concepts, symbolic notation, algorithmic actions, graphical models, cause-and-effect relationships, and multi-stage problem-solving methods. If a learner does not understand one of the intermediate steps, further learning quickly becomes more difficult. For this reason, a future STEM teacher must be prepared not only to transmit subject content but also to notice individual difficulties, change the way of explaining material, select different forms of presenting content, adapt the pace of work, and support learners in situations of error, uncertainty, or loss of learning motivation.

Contemporary studies of personalized STEM education often associate its development with digital technologies, adaptive platforms, learning analytics, and artificial intelligence tools. In particular, reviews of studies on this issue show that artificial intelligence can support individual learning trajectories, task selection based on preparation level, feedback provision, and the identification of learning gaps (Sun et al., 2025). Studies on the use of AI in teacher training also show that digital tools can help organize inclusive learning, diversify teaching methods, and promote the development of teachers' digital literacy (Zhang & Zhang, 2024). However, these opportunities do not eliminate the teacher's leading role. On the contrary, they make this role more complex, since the teacher must not only use technology, but also understand its limits, pedagogical appropriateness, ethical risks, and influence on learner autonomy.

Therefore, personalization of learning should be considered not as a purely technological function of a digital system, but as a teacher's professional capacity. It is manifested in the ability to recognize the nature of a learning difficulty, see a particular way of thinking behind an error, adapt the content or form of a task, propose an alternative explanation, and support the learner without lowering learning requirements. In this understanding, personalization is an integrated soft skill for the pre-service STEM teacher. It combines methodological flexibility, inclusive sensitivity, emotional competence, digital literacy, pedagogical reflection, and the ability to act under unpredictable conditions. This is especially important for the training of a teacher who will work not in an idealized digital classroom, but in a real educational environment where technical, social, psychological, and organizational conditions may change rapidly.

Inclusive education strengthens the need for such pedagogical capacity. Its essence lies not only in the physical presence of a learner in a common classroom, but also in ensuring real participation in the educational process, accessibility of learning content, acceptability of modes of activity, and the possibility of achieving outcomes in accordance with one's own needs and capacities. Studies of inclusive education emphasize that effective teaching in a diverse classroom requires teachers to have a positive attitude toward inclusion, a belief in their ability to support diverse learners, and practical skills for adapting the learning environment (Woodcock et al., 2023). In STEM disciplines, this means the ability to adapt mathematical texts, formulas, algorithms, graphs, diagrams, models, and modes of explanation so they are understandable to learners with diverse cognitive and sensory characteristics.

Learners with dyslexia may need shorter instructions, a larger font size, visual structuring of text, color-coded marking of formula elements, or a separate oral explanation. Learners with dyscalculia may better understand mathematical concepts through object-based models, number lines, diagrams, manipulatives, and geometric interpretations. For learners with attention difficulties, short steps, a clear sequence of actions, more frequent feedback signals, and reduced overload with secondary information are important. Learners with autism spectrum disorders may need a predictable lesson structure, a visual plan for the activity, and clear rules for transitions between work stages. All this requires from the teacher not only knowledge of specific techniques, but also the readiness to quickly restructure pedagogical action in response to the situation.

The theoretical basis for this understanding of personalization is Universal Design for Learning, differentiated instruction, and technological, pedagogical, and content knowledge. Universal Design for Learning guides the teacher toward creating conditions in which different ways of presenting material, engaging in activity, and demonstrating results are anticipated in advance, rather than added only after difficulties arise. Studies on the implementation of Universal Design for Learning in higher education confirm its importance for increasing accessibility, engagement, and understanding of learning material among different groups of learners (Chavarría et al., 2023; Ismailov & Chiu, 2022). Differentiated instruction, in turn, emphasizes the need for continuous pedagogical assessment of learners' readiness, interests, pace, and learning profile. Empirical studies show that differentiated instruction can help overcome learning gaps in mathematics and increase learners' confidence in completing tasks of varying complexity (Aguhayon et al., 2023; Samsudi et al., 2024).

In pre-service STEM teacher training, it is also important to consider the TPACK framework, which describes the relationships among technological, pedagogical, and content knowledge. Its significance lies in the fact that technology is not considered separately from the discipline's content and its teaching methodology. An effective digital solution in STEM education must be accurate in terms of subject content, pedagogically appropriate, and technically feasible. At the same time, contemporary studies of teachers' digital competence show that mere technical skills do not guarantee high-quality pedagogical practice. The teacher must be able to select technology based on the educational purpose, learners' characteristics, available resources, and potential limitations (Gómez-Pablos et al., 2022; Mattar et al., 2022). This point is especially significant in educational settings where Internet access is unstable or absent.

Unstable Internet access disrupts the very logic of personalized learning. Under technically stable conditions, the teacher can rely on online tests, electronic courses, videos, interactive simulations, automated hints, LMS analytics, shared documents, and digital boards. However, under conditions of connection interruptions, limited power supply, or learning in a shelter, such solutions may be unavailable. In this situation, it becomes clear whether the teacher is able to transfer the pedagogical logic of personalization into an offline format: to prepare paper-based individual routes, use cards of different difficulty levels, create a diagram on the board, propose an object-based model, organize pair work, provide oral feedback, and record observations without online tools. Studies of digital education in resource-limited contexts confirm that the lack of infrastructure, weak Internet connectivity, and insufficient technical support remain significant barriers to implementing technology; therefore, pedagogical decisions must be flexible and not overly dependent on the digital environment (Ofosu-Asare, 2024; Okoye et al., 2022).

For Ukrainian education, this problem is particularly acute. Blended and distance learning, asynchronous interaction, interrupted lessons, uneven access to digital resources, and the need for rapid transition from online formats to offline activity have become part of everyday pedagogical practice. Therefore, a pre-service STEM teacher must be prepared not only to use digital tools under favorable conditions, but also to organize the educational process when technological support is incomplete. This does not mean rejecting digitalization. On the contrary, such readiness indicates a mature digital-pedagogical stance: the teacher understands that technology should support learning but should not be the sole condition for its implementation.

In this regard, personalization of learning is closely connected with the teacher's emotional competence. An inclusive STEM classroom is not only a space for subject explanation. It is also a space for emotional interaction, where the learner may fear making mistakes, feel ashamed of their own difficulties, avoid difficult tasks, or lose confidence in their abilities. A systematic review of studies on teacher emotional competence in inclusive education shows that the teacher's capacity for empathy, self-regulation, support of a positive climate, and attentive response to learners' emotional states affects their engagement, motivation, and academic outcomes (Calandri et al., 2025). Therefore, personalization in inclusive STEM education cannot be a purely cognitive procedure. It must include supportive pedagogical communication, recognition of the learner's difficulties, and the creation of safe conditions for asking questions and trying out actions.

No less important is the future teacher's capacity for critical and reflective thinking. Personalization cannot be built on the mechanical application of ready-made recommendations. It requires analyzing a specific situation, selecting an appropriate pedagogical tool, verifying its effectiveness, and correcting subsequent actions. Active, problem-oriented, and project-based learning in the training of future teachers is considered one of the ways to develop such skills, as it encourages future educators to work with open-ended tasks, analyze alternative solutions, cooperate, and evaluate the consequences of their own actions (Doolittle et al., 2023; Rehman et al., 2024). In STEM teacher training, this is especially significant, since learners' real educational difficulties rarely fit into a single typical scenario.

Despite the considerable body of research on personalized learning, inclusion, digital competence, and STEM education, the capacity of future teachers to personalize learning specifically under conditions of unstable or absent Internet access remains insufficiently studied. Most digitally oriented approaches assume access to a platform, device, electronic content, or online communication. Instead, pedagogical practice requires an answer to another question: is the future teacher capable of acting in a personalized way when these tools are unavailable? This situation allows us to see whether they have developed a methodological logic of personalization or merely possess separate digital tools.

This underscores the need to diagnose the capacity for personalization of learning as a distinct, professionally significant quality of the pre-service STEM teacher. Such diagnostics should include not only knowledge of terms and attitudes toward inclusion, but also the ability to act in situations that closely resemble real practice. Appropriate tools include paper-based cases in which it is necessary to analyze a learning difficulty and propose an offline adaptation; tasks for creating an individual route for a learner with specific educational needs; modeling a lesson fragment without Internet access; and expert evaluation of specific pedagogical actions. Such an approach allows assessment not only of what the future teacher knows about personalization, but also of how they act when faced with limited resources, diverse educational needs, and the need for rapid pedagogical decisions.

Thus, the problem addressed in this chapter is the need to theoretically substantiate and empirically describe pre-service STEM teachers' capacity to personalize learning in inclusive education under conditions of unstable Internet access. This is a capacity that cannot be replaced by a digital service and cannot be reduced to the use of a ready-made adaptive platform. It is formed through the combination of subject preparation, methodological flexibility, inclusive pedagogy, digital literacy, emotional support, and reflective analysis of one's own actions. Its development is an important condition for training a teacher capable of ensuring the accessibility of STEM education not only under technically favorable conditions, but also in situations of educational instability, when it is the pedagogical decision, rather than the technological tool, that determines the possibility of a learner's progress.

Literature Review

The problem of personalization of learning in STEM education arises at the intersection of several research areas: personalized and adaptive learning, inclusive education, teachers' digital competence, professional training of future teachers, development of soft skills, and the organization of the educational process under conditions of unstable access to digital infrastructure. In the scholarly literature, these areas are often considered separately. Personalization is associated with digital platforms and artificial intelligence; inclusion with the accessibility of the educational environment and the adaptation of learning material; digital competence with teachers' readiness to use technologies; and soft skills with emotional, communicative, and reflective readiness for pedagogical interaction. However, in pre-service STEM teacher training, these dimensions should be considered together, as real pedagogical action requires their integration.

In contemporary research, personalized learning in STEM education is often described as an approach that involves adapting content, pace, modes of presenting material, and learning tasks to the needs of a specific learner. Sun et al. (2025), in their analysis of AI-supported personalized STEM education, show that AI tools can expand opportunities to adapt learning trajectories, provide individualized feedback, identify learning gaps, and select tasks based on the learner's level of preparation. This view aligns with the broader trend of digitalization in education, in which personalization is often associated with learning analytics, adaptive algorithms, automated assessment, and digital recommendation systems.

At the same time, these approaches reveal a methodological tension. On the one hand, digital technologies enable the analysis of large amounts of learning data and the rapid response to learners' individual outcomes. On the other hand, personalization cannot be fully automated, since it involves pedagogical interpretation of the situation, ethical decision-making, emotional support, and an understanding of the personal circumstances of learning. Zhang and Zhang (2024) emphasize that artificial intelligence in teacher education opens new opportunities for supporting teaching, inclusive learning, and digital literacy, but these opportunities depend on the teacher's capacity to use technology critically and with pedagogical justification. Thus, the technological potential of personalization does not eliminate the need for the teacher's professional judgment.

This idea is reinforced by studies examining the risks of excessive reliance on artificial intelligence in education. Jose et al. (2025) describe the so-called cognitive paradox of AI: on the one hand, AI tools can support learning, reduce cognitive load, and help learners overcome complex tasks; on the other hand, uncritical use of such tools may weaken independent thinking, creative activity, and deep conceptual understanding. For STEM education, this problem is particularly significant, since learning mathematics, computer science, or natural sciences cannot be reduced to obtaining the correct answer. It requires understanding the reasoning process, constructing a model, analyzing an error, and testing a hypothesis. Therefore, personalization should support not only the result but also the learner's thinking process.

Differentiated instruction is closely related to personalization, though the two are not identical. Differentiation usually involves varying content, process, product, or level of complexity based on learners' group or individual differences. Personalization is broader, encompassing not only task adaptation but also consideration of educational trajectory, motivation, pace, modes of self-expression, need for support, and level of autonomy. The study by Samsudi et al. (2024), devoted to differentiated instruction within the Merdeka Curriculum, shows that the success of this approach depends on the accuracy of pedagogical assessment, the quality of the organization of the differentiated learning process, and the teacher's ability to propose different learning outcomes. These findings are important for understanding personalization, as they show that adaptation begins not with the choice of a tool, but with diagnosing the learning situation.

In mathematics, differentiated instruction has particular evidentiary value. Aguhayon et al. (2023) showed that differentiated instruction to address gaps in mathematical preparation improves learning outcomes and increases learner confidence. This finding is important for the training of future teachers, since mathematical difficulties often have a cumulative character: misunderstanding basic concepts or procedures makes it impossible to move on to more complex topics. Therefore, the teacher must be able not merely to repeat an explanation, but to determine exactly where the difficulty lies and propose another way of working with the material. It is here that differentiated instruction becomes a more subtle pedagogical approach: personalization.

Universal Design for Learning is a significant theoretical framework for analyzing personalization. Unlike approaches in which adaptation occurs after difficulties have been identified, UDL provides for the design of learning that takes learner diversity into account from the outset. Chavarría et al. (2023) demonstrate that Universal Design for Learning in higher education contributes to creating a more accessible educational environment through multiple means of presenting information, engaging learners in activities, and demonstrating results. Ismailov and Chiu (2022), in their analysis of asynchronous online learning based on UDL, also show that well-designed courses can support engagement and perceived availability of learning support across different groups of learners. For the topic of this chapter, it is important that UDL can be applied not only in digital but also in offline formats: through different modes of explanation, printed materials, diagrams, object-based models, and alternative forms of response.

In the context of inclusive education, personalization acquires not only methodological but also ethical significance. Jardinez and Natividad (2024) emphasize that inclusive education should aim to ensure equitable access to learning for all learners, including those with special educational needs. However, the declaration of inclusion itself does not guarantee its practical implementation. Woodcock et al. (2023) show that teachers' beliefs about inclusive education are related to their self-efficacy: teachers with more positive attitudes toward inclusion tend to have greater confidence in their ability to implement inclusive practices. This has direct significance for the training of pre-service STEM teachers, since inclusive personalization requires not only knowledge of special educational needs but also an internal readiness to act in a heterogeneous classroom.

Teachers' professional development in inclusion is also actively examined in contemporary meta-analytic studies. Donath et al. (2023) found that professional development programs can positively affect teachers' knowledge, skills, and behavior regarding inclusive education, although the strength of the effect varies: the most noticeable changes are often observed at the level of knowledge, while the transfer of this knowledge into real practice is more difficult. This finding is fundamental to the study of the capacity for personalized learning. It shows that it is not enough to teach future teachers terms or general principles of inclusion. Practical situations, modeling, case analysis, pedagogical trials, and expert evaluation of specific actions are needed. Only then can one speak of a developed capacity, rather than mere awareness.

A separate body of research concerns teachers' digital competence. Gómez-Pablos et al. (2022), in a systematic review of studies on the digital competences of higher education teachers, note that educators often assess their own digital competence as low or medium, especially in the areas of assessment and pedagogically meaningful use of technologies. Mattar et al. (2022), comparing international frameworks of digital competence, identify common components: information and data literacy, communication, collaboration, digital content creation, safety, ethical responsibility, and the use of technologies for learning. These studies allow an important conclusion to be drawn: a teacher's digital competence cannot be limited to operational mastery of services. It must include pedagogical judgment about when technology is appropriate and when a learning task requires another mode of organization.

The problem of AI literacy among future teachers is also being actively addressed. Ayanwale et al. (2024) show that future teachers' understanding of artificial intelligence is related to their readiness to use AI tools, identify bias, consider ethical issues, and solve professional tasks. Chee et al. (2024) propose a framework of AI literacy competences that provides for gradual development from a basic understanding of AI to the ability to analyze data, algorithms, ethical risks, and applied possibilities of the technology. For STEM teacher training, these results are important, but they also indicate the limits of the technological approach. Even at a high level of AI literacy, the teacher must be ready to act when AI tools are unavailable or their use is pedagogically inappropriate.

The generational dimension of generative AI adoption should also be taken into account, since differences between learners' and teachers' readiness to use AI tools may influence the design of personalized learning and the need for explicit pedagogical guidance (Chan & Lee, 2023).

For this study, research on educational practices under conditions of unstable or limited access to digital infrastructure is particularly important. Ofosu-Asare (2024), analyzing opportunities for developing ICT methodologies for teachers in rural schools in Ghana without access to computers or the Internet, shows that effective technological integration in resource-limited environments should rely on available tools, professional teacher support, locally relevant resources, and community participation. This study is important because it shifts the focus from technological deficits to pedagogical inventiveness and resilience. A lack of Internet access does not necessarily mean personalized learning is impossible, as teachers can use flexible methodological solutions.

Similar findings can be traced in studies of digital technologies in higher education. Okoye et al. (2022), analyzing the impact of digital technologies on teaching and learning in Latin America, show that insufficient teacher preparation, limited infrastructure, lack of resources, and uneven Internet access remain among the main barriers. These factors not only complicate the use of digital tools but may also deepen educational inequality if the pedagogical model depends completely on stable technological support. For the training of future teachers, this means that digital competence should be supplemented by the capacity for offline learning design.

The experience of distance and online learning during the COVID-19 pandemic has also become an important source for understanding the limitations of digital education. DeCoito and Estaiteyeh (2022), studying the practices of Canadian STEM teachers during online learning, showed that teachers actively used video recordings, independent work, and digital resources, but also faced difficulties in assessment, support for different educational needs, and ensuring genuinely inclusive interaction. This indicates that the transition to a digital environment does not in itself guarantee personalization. On the contrary, it may make more visible those pedagogical difficulties that, in face-to-face formats, were compensated for by direct interaction.

In studies of adaptive learning, particular attention is paid to mobile and multimodal solutions. Sayed et al. (2022) describe an AI-based adaptive platform that presents material in different VARK modalities and navigates tasks adaptively. Such systems demonstrate potential for increasing learner engagement and learning effectiveness. However, these solutions require technological infrastructure, access to devices, a stable connection, and teachers' readiness to interpret the data obtained. Therefore, for educational systems with uneven digital access, they cannot be the only model of personalization. Parallel offline strategies are needed that preserve the pedagogical logic of adaptation without complete dependence on the digital environment.

An important aspect of personalization is the teacher's emotional competence. Calandri et al. (2025), in a systematic review of studies on teacher emotional competence in inclusive education, emphasize that teachers' ability to recognize learners' emotional states, support a positive climate, show empathy, and regulate their own reactions affects engagement, motivation, and academic achievement. In STEM education, this is especially important, since mathematical or technical errors are often accompanied by anxiety, reduced confidence, and avoidance of complex tasks. If the teacher personalizes only the content, but does not support the learner emotionally, such personalization remains incomplete.

Henriksen et al. (2025), in their analysis of socio-emotional learning and generative AI in teacher education, emphasize the need to combine technological literacy with teachers' emotional, ethical, and social responsibility. This position is important for understanding personalization as a soft skill. Personalization is not a mechanical adjustment of task difficulty. It involves attentiveness to the person, the ability to support their autonomy, competence, and sense of belonging to the learning community. In this sense, personalized learning aligns with the ideas of self-determination theory, which holds that motivation and engagement are related to the satisfaction of needs for autonomy, competence, and relatedness (Chiu et al., 2024; Ismailov & Chiu, 2022).

Studies of teachers' professional development also show that developing capacity for personalization requires not only lecture-based explanations but also active learning. Doolittle et al. (2023), in a systematic review of active learning, emphasize that it involves learners' participation in activities that require analysis, application, evaluation, and creation. Rehman et al. (2024), in their study of project-based learning as a means of developing twenty-first-century skills in the mathematics classroom, highlight its significance for fostering critical thinking, problem-solving, and engagement. For the training of pre-service STEM teacher s, this means they should not only study personalization as a concept but also engage in case studies, pedagogical simulations, the design of adapted materials, the analysis of video fragments, and reflection on their own actions.

Research devoted to preparing pre-service STEM teachers for differentiated and inclusive learning deserves separate attention. Estaiteyeh and DeCoito (2023) show that the purposeful inclusion of resources for differentiated instruction and equity, diversity, and inclusion in STEM courses for future teachers contributes to the development of the ability to plan learning with learner diversity in mind. Hughes et al. (2022) propose integrating the arts with STEM to strengthen equity in science learning for emerging bilingual learners. Both studies are important because they move beyond narrow subject teaching. They show that a pre-service STEM teacher should view classroom diversity not as an obstacle but as a condition to be taken into account in learning design.

At the same time, contemporary literature pays insufficient attention to diagnosing the capacity for personalization as a separate outcome of future teachers' professional training. Many studies assess attitudes toward inclusion, levels of digital competence, readiness to use AI, knowledge of UDL principles, or the effectiveness of differentiated methods. However, fewer studies examine how a future teacher actually behaves in a specific pedagogical situation when several complicating factors are present simultaneously: a learner's special educational needs, complex STEM content, limited time, lack of Internet access, need for emotional support, and the need to rapidly select an alternative explanation. Such a situation allows us to see whether the capacity for personalization has been formed not at the declarative level, but at the practical level.

Thus, the analysis of current research provides grounds for several generalizations. Personalized learning in STEM education is increasingly supported by digital and AI-oriented technologies, but it cannot be reduced to them. Inclusive education requires from the teacher not only knowledge of different categories of educational needs, but also a real capacity to adapt content, mode of explanation, pace, and form of feedback. Unstable Internet access reveals the limits of technology-dependent personalization and actualizes the need for offline-oriented pedagogical solutions. The capacity for personalizing learning should be considered an integrated soft skill for the pre-service STEM teacher , encompassing methodological, digital, inclusive, emotional, and reflective components. There is also a need for diagnostic approaches that enable assessment not only of future teachers' knowledge or attitudes, but also of their actual actions in simulated inclusive situations under limited resources.

In this study, differentiation, personalization, and an individual learning route are considered as interrelated but not identical concepts. Differentiation means varying content, complexity, work mode, or pace according to learners' differences. Personalization is a broader concept, as it involves not only task adaptation but also consideration of specific learning difficulty, educational trajectory, level of autonomy, emotional state, and need for support. An individual learning route in this study is considered a practical tool of personalization through which the teacher plans a sequence of learning actions, adaptations, and forms of feedback for a specific learner.

Taking into account the theoretical analysis of the problem of personalization of learning in STEM education, inclusive pedagogy, and the training of future teachers to work under conditions of unstable digital access, the study aimed to answer the following research questions.

Research Question 1. What components of pre-service STEM teacher s' capacity for personalization of learning are most significant for organizing an inclusive educational process under conditions of unstable or absent Internet access?

This question concerns clarifying the content of the capacity for personalization of learning, not as a general pedagogical intention, but as a specific professional quality of the future teacher. In the study, this capacity is considered through the ability to diagnose learners' individual difficulties, adapt STEM content, select alternative ways of explanation, organize offline differentiation, support different learning paces, and ensure emotionally safe interaction. Such a formulation is consistent with the approaches of Universal Design for Learning and differentiated instruction, within which learning accessibility is ensured not through separate accommodations after difficulties arise, but through flexible design of educational activity from the beginning

(Chavarría et al., 2023; Ismailov & Chiu, 2022; Samsudi et al., 2024).

Research Question 2. What changes occur in future mathematics teachers’ capacity for personalization of learning after a short-term training intervention aimed at developing offline-oriented inclusive pedagogical solutions?

This question is empirical in nature. It involves comparing participants’ results before and after the formative intervention. Particular attention is paid not only to the quantitative change in scores, but also to the qualitative change in pedagogical decisions: whether future teachers move from general or digitally dependent responses to specific offline adaptations; whether they are able to propose alternative explanations; and whether they use paper-based, visual, object-based, and communicative means of supporting learners with different educational needs. Such an approach aligns with the logic of research on teachers’ professional development, which emphasizes assessing not only increases in knowledge but also their transfer into practical pedagogical action (Donath et al., 2023).

Research Question 3. To what extent do paper-based cases, tasks for creating an individual learning route, and expert evaluation of a video recording of a lesson fragment make it possible to identify future teachers’ practical readiness for personalization of learning in inclusive situations without Internet access?

This question concerns the diagnostic toolkit. It is important because the capacity for personalized learning is difficult to assess solely through a test or self-assessment. A future teacher may know the terminology, have a positive attitude toward inclusion, and declare readiness for personalization, but act in a stereotyped way in a real or simulated pedagogical situation. Therefore, the study used a set of tasks that bring participants closer to practical conditions: case analysis, creation of a paper-based individual route, modeling of a lesson fragment under fully offline conditions, and expert evaluation of specific pedagogical actions. This approach is consistent with the broader methodology of mixed-methods pedagogical research, in which quantitative indicators are supplemented by qualitative analysis of participants' responses and behavioral manifestations (Creswell & Creswell, 2018).

Research Methods

The study was organized as a pilot one-group quasi-experimental study with a mixed-methods data analysis. Its purpose was not only to record changes in quantitative indicators of future teachers' capacity for personalization of learning, but also to describe the nature of the pedagogical decisions they proposed in simulated inclusive situations under conditions of unstable or absent Internet access. Such a design is appropriate for preliminary pedagogical research when the aim is not to compare two independent groups, but to identify the dynamics of indicators within one group before and after a specifically designed formative intervention.

The study combined theoretical and empirical stages. At the theoretical stage, scholarly sources were analyzed on the problems of personalized learning in STEM education, inclusive education, Universal Design for Learning, differentiated instruction, teachers' digital competence, AI literacy, soft skills of future teachers, and learning under conditions of limited access to digital infrastructure. This stage clarified the content of the capacity for personalization of learning as an integrated professional quality of the pre-service STEM teacher. Within the analysis, three main criteria of this capacity were identified: diagnosing learners' individual educational needs; adapting STEM content, particularly mathematical material; and organizing offline differentiation and learning support under conditions of unstable Internet access.

The empirical stage was based on the design "pre-test – formative intervention – post-test." This logic enabled comparison of participants' initial and final levels of capacity for personalizing learning and determination of changes following the short-term training intervention. All participants completed a specially developed training program designed to develop the skills for personalizing mathematics learning in an inclusive, offline-oriented environment.

The participants in the pilot study were 38 future mathematics teachers enrolled in pedagogical programs in mathematics and computer science. All participants formed one research group, whose results were compared at the pre-test and post-test stages. The study involved learners who already had basic methodological training and general digital skills, but had not previously received systematic training in offline differentiation and personalization of learning under conditions of unstable Internet access. This selection of participants was important because the study aimed to identify how future teachers transfer general methodological knowledge into situations of inclusive pedagogical action under limited resources.

Since the study was a pilot and conducted in real conditions of future teacher training, no control group was formed. The main task was to trace changes within one group of participants after the specially organized training. Therefore, the results were interpreted with regard to the limitations of a one-group design: the observed positive dynamics may be associated with the formative intervention but require further verification in studies with control groups and larger samples.

The main diagnostic tools were paper-based cases, a rubric for expert evaluation of a lesson fragment video recording, and a task to create an individual learning route. This set of tools was chosen because the capacity for personalization of learning has a behavioral and situational character. It is difficult to assess only through a knowledge test or a self-assessment questionnaire. A future teacher must not only know what inclusion, differentiation, or personalization means, but also be able to act in a specific situation: to identify a learner's difficulty, propose an adaptation, explain the material in another way, use available resources, and support a learning activity without a digital platform.

The first tool was the set of paper-based cases "Personalization under Conditions of a Limited Network." These cases described pedagogical situations in which the future teacher had to work with a learner who had certain difficulties or special educational needs, under conditions of unstable or absent Internet access. Each case required a written response in which the participant had to identify the nature of the learning difficulty, propose a way to clarify it without online testing, select at least two variants of explanation, adapt the next task, and determine the form of feedback. The maximum total score for the case block was 24 points. Assessment was carried out according to three parameters: accuracy of difficulty diagnosis, appropriateness and specificity of adaptation, and use of offline personalization methods.

The second tool was the rubric for evaluating a video recording of a lesson fragment. Participants completed a 20-minute pedagogical modeling task in which actors played the roles of learners with different learning difficulties, including slower work pace, dyslexia, or concentration difficulties. The modeling was conducted under fully offline conditions: without access to the Internet, online platforms, videos, or digital simulators. The available resources were a board, paper cards, markers, felt-tip pens, diagrams, and simple object-based or visual materials. This format enabled assessment not only of planning but also of the future teacher's actual behavior in a pedagogical situation.

The rubric contained five criteria, each assessed on a scale of 0 to 2 points: identification of individual difficulties; variability of explanation; adaptation of pace; use of offline resources; and emotional support for the learner. The maximum score for the video rubric was 10 points. Assessment was conducted by an independent expert according to predefined descriptors. This tool was selected because it enables observation of practical actions that are not always captured in written responses, such as whether the future teacher asks diagnostic questions, notices when a learner stops, adjusts the explanation, supports the pace, and responds to emotional manifestations of uncertainty.

The third tool was a control task for creating an individual learning route. The participant received a brief description of a learner’s educational profile: typical errors, pace of work, strengths, difficulties, and possible special educational needs. The task was to propose, within a limited time, a plan for several subsequent mathematics lessons, determine the sequence of tasks, ways of adapting the material, the form of feedback, and support options in offline mode. Assessment was carried out using a checklist that recorded the presence of specific adaptations, the logic of the route, the correspondence of tasks to the learner’s needs, anticipation of alternative ways of explanation, and feasibility without the Internet.

The pre-test involved completing basic paper-based cases, a short task to create an individual route, and modeling a lesson fragment under conditions that did not involve a particularly complex digital situation. Its purpose was to determine the initial level of future teachers' capacity for personalization of learning and to record typical difficulties. Particular attention was paid to whether participants could propose specific offline adaptations or whether their decisions remained general or overly reliant on digital tools.

The formative intervention was implemented as a short-term training program titled "Personalization of Mathematics Learning in an Inclusive Offline/Unstable Environment." The training lasted 12 hours, divided into six 2-hour sessions. The content of the training covered diagnosis of learning difficulties without online testing, adaptation of mathematical text, creation of paper-based personalized cards, selection of alternative explanations, variable feedback without the use of a chat or LMS, modeling of a lesson under conditions of complete absence of connection, and analysis of video recordings of participants' own pedagogical trials.

The first session was devoted to diagnosing learning difficulties through observation, pedagogical conversation, analysis of written work, and typical errors. The second session focused on adapting mathematical text: simplifying instructions without losing content; dividing a task into short steps; using a larger font; using color to structure; using diagrams; and using markings. The third session involved creating paper-based personalized cards for learners with different needs: dyslexia, dyscalculia, attention difficulties, and a slower pace of work. The fourth session focused on variable real-time feedback: oral clarification, short hints, support signals, and repeated explanation using another model. The fifth session was conducted in the format of an integrated lesson modeling without access to the Internet. The sixth session was devoted to viewing and analyzing video recordings of pedagogical trials, reflection, and correction of individual strategies.

The post-test was conducted after the formative stage. It included more complex paper-based cases, a repeated task for creating an individual route, and a video recording of a lesson fragment under fully offline conditions. At this stage, a situation was modeled in which the participant could not use an online video, an electronic textbook, an automated test, a chatbot, or an LMS. This made it possible to assess whether the future teacher could act in a personalized way without digital support: ask clarifying questions, identify the cause of an error, adjust the explanation, use the board, paper materials, object-based or visual supports, and support the learner emotionally.

Quantitative data processing involved calculating descriptive statistics for the pre-test and post-test results: mean, standard deviation, median, minimum, and maximum scores. To compare the results before and after the formative intervention, the Wilcoxon signed-rank test for related samples was used, since the sample was small and the distribution of results could deviate from normality. This approach corresponds to the pilot one-group design and allows for determining whether the changes between the pre-test and post-test are statistically significant. At the same time, the results were interpreted cautiously, as the absence of a control group precludes a strong causal conclusion.

Several procedures were used to enhance the study's validity. First, three different assessment tools were applied: cases, an individual route, and video modeling. This made it possible to compare written decisions, planning skills, and practical behavior. Second, the post-test conditions were close to real-world situations of educational instability, in which the Internet is unavailable, and the teacher must work with a limited set of resources. Third, expert evaluation using a rubric with predefined criteria was used for the video recordings, reducing the risk of arbitrary interpretation of pedagogical actions. Fourth, quantitative results were supplemented by qualitative analysis of responses, which enabled explanation not only of changes in indicators, but also of their content.

The ethical aspects of the study included voluntary participation, informing participants about the study's purpose and procedures, maintaining the confidentiality of results, coding video recordings, and using the obtained data only in a general form.

Participants were informed that the simulated technical limitations were not a test of their technical proficiency but were intended to identify pedagogical actions under conditions of limited resource access. This was important for reducing unnecessary stress and ensuring an appropriate attitude toward the experimental situation.

The pilot nature of the study also determined certain methodological limitations. First, the sample was small, so the results cannot be automatically generalized to all pre-service STEM teachers. Second, the study was conducted mainly with future mathematics teachers, so further verification is needed for other STEM fields. Third, the offline situations were simulated rather than fully natural, although they reproduced typical difficulties in the educational process under unstable Internet access. Fourth, expert evaluation of video recordings, despite the use of a rubric, remains to some degree subjective, requiring the involvement of multiple experts and verification of inter-rater agreement in future research.

Thus, the research methodology aimed to comprehensively identify pre-service STEM teachers' capacity to personalize learning in inclusive conditions with unstable Internet access. Its specificity lay in the fact that the assessment covered not only knowledge or attitudes toward personalization, but also specific pedagogical actions: diagnosis of difficulties, adaptation of content, selection of offline resources, variability of explanation, support of pace, and emotional interaction with the learner. This approach makes it possible to consider the capacity for personalized learning as a measurable, developable soft skill of the pre-service STEM teacher.

Research Results

The results of the pilot study are presented in three interrelated blocks: the dynamics of completing paper-based cases, the results of expert evaluation of the video recording of a lesson fragment, and the qualitative analysis of participants' open responses and pedagogical decisions. This logic corresponds to the study's mixed one-group design, since the capacity for personalization in learning cannot be fully captured by a single total score. It manifests in how the future teacher analyses a learning situation, the adaptations they propose, and how they act during simulated interactions with a learner.

Within the study, the capacity for personalizing learning was considered an integrated professional quality of a pre-service STEM teacher , encompassing three main dimensions: diagnosis of individual learning difficulties, adaptation of mathematical material, and organization of offline differentiation under conditions of unstable or absent Internet access. Variability of explanation, ability to adapt pace, use of available offline resources, and emotional support for the learner were also taken into account.

1. Results of Completing Paper-Based Cases

The first block of empirical data concerned the completion of paper-based cases, with a maximum possible score of 24 points. The cases aimed to identify how future teachers analyze an inclusive pedagogical situation, whether they can determine the nature of a learning difficulty, propose adaptations to the mathematical material, and organize support without relying on online resources.

At the pre-test stage, the participants' mean score for paper-based cases was M = 8.42, SD = 4.65, with a median of 8. The results ranged from 3 to 16 points. This indicates that, at the beginning of the study, future teachers' capacity to analyze inclusive pedagogical situations and propose specific offline adaptations was unevenly developed. Some participants recognized the general need for support, but most responses remained insufficiently specific or relied on digital resources.

After the formative intervention, a noticeable increase in results was recorded. The mean score increased from 8.42 to 17.42, yielding an average gain of 9.00 points. The median increased from 8 to 17.5 points. The minimum post-test result was 7 points, and the maximum was 24 points. In 35 of 38 participants, an increase in the result was observed; two participants showed no change, and one showed a slight decrease. Thus, the positive dynamics were almost general (Table 1).

Table 1
Descriptive Statistics for the Results of Completing Paper-Based Cases

Stage	N	M	SD	Me	Min	Max
Pre-test	38	8.42	4.65	8.00	3	16
Post-test	38	17.42	4.87	17.50	7	24

Source: Authors' own work.

The statistical verification of the dynamics confirmed the significance of the changes. According to the Wilcoxon test, the gain in the paper-based case results was statistically significant, $p < .001$. This provides grounds for stating that, after the formative intervention, participants demonstrated a higher capacity to analyze inclusive pedagogical situations, identify learning difficulties more accurately, and propose more specific offline adaptations.

The substantive interpretation of the results shows that, before the training, a significant proportion of participants formulated their responses in a general or technologically dependent way. Typical responses included formulations such as "give an additional video," "offer an online test," "send the material to Google Classroom," or "find a simpler explanation on the Internet." Such responses indicated an understanding of the need for assistance, but did not demonstrate readiness to act without digital support. After the training, participants more often proposed specific offline adaptations: paper-based cards with varying levels of difficulty, number lines, diagrams, step tables, visual breakdowns of a formula, work with magnetic fractions, drawing on the board, object-based models, oral articulation of an algorithm, and individual mini-routes.

The change in the way pedagogical action was described was especially noticeable. Whereas at the pre-test stage some participants responded through the intention to "explain once again," at the post-test stage more precise formulations appeared: "first check at which step the learner stops," "present the same equation as a balance-scale diagram," "divide the solution into three cards," "mark identical elements of the formula with colour," or "give the learner with dyslexia the formula in large font and say it aloud." This indicates a transition from general assistance to more conscious personalization.

2. Results of Expert Evaluation of the Video Recording of a Lesson Fragment

The second block of results concerned the video recording of a 20-minute lesson fragment, which was assessed against five criteria: identification of individual difficulties, variability in explanations, adaptation of pace, use of offline resources, and emotional support. The maximum score according to the rubric was 10 points.

At the pre-test stage, the mean total score according to the video rubric was M = 3.03, SD = 1.75, with a median of 3 points. This indicates that, before the formative intervention, participants' practical behavioral readiness for personalizing learning under offline conditions was low. Participants were generally able to maintain interaction, but rarely demonstrated a complete personalization cycle: diagnosis of difficulty, adaptation of explanation, change of pace, use of an offline resource, and emotional support.

After the formative intervention, the results according to the video rubric increased substantially. The mean total score increased from 3.03 to 8.32 points, and the median increased from 3 to 8 points. The minimum post-test result was 5 points, and the maximum was 10 points. In 37 out of 38 participants, an increase in the result was recorded; one participant remained at the same level, and no decrease was observed (Table 2).

Table 2
Descriptive Statistics for the Results of Evaluating the Video Recording of a Lesson Fragment

Stage	N	M	SD	Me	Min	Max
Pre-test	38	3.03	1.75	3.00	0	7
Post-test	38	8.32	1.51	8.00	5	10

Source: Authors' own work.

The statistical analysis showed significant positive dynamics according to the video rubric ($p < .001$). This indicates that, after the training, participants not only described possible adaptations more effectively in writing, but also more often implemented personalized pedagogical action in a simulated offline situation (Table 3).

Table 3
Mean Results by Video Rubric Criteria

Criterion	Pre-test	Post-test	Gain
Identification of individual difficulties	0.50	1.37	+0.87
Variability of explanation	0.37	1.76	+1.39
Adaptation of pace	0.29	1.76	+1.47
Use of offline resources	0.87	1.53	+0.66
Emotional support	1.00	1.89	+0.89

Source: Authors' own work.

An analysis based on separate criteria allows more precise identification of where the changes occurred. The greatest increase was observed for the criteria "variability of explanation" and "adaptation of pace." This is important because these two indicators directly reflect the teacher's capacity not merely to continue the lesson, but to adapt pedagogical action in response to the learner's response. A noticeable increase was also observed for the criterion "emotional support," indicating the strengthening of supportive communication as a component of personalization.

At the pre-test stage, pedagogical behavior was more often linear. Participants followed a previously chosen explanation and did not always change it, even when the actor demonstrated misunderstanding. Typical phrases included "think again," "try more carefully," "we have already done this," or "I will explain later." At the post-test stage, different types of actions appeared: participants drew a balance diagram to explain equations, decomposed the formula for the square of a binomial through the area of a square, marked identical elements with colour, gave a card with intermediate steps, and suggested articulating the algorithm aloud. These changes indicate a transition from general instruction to personalized pedagogical support.

3. Qualitative Analysis of Open Responses

The qualitative analysis of open responses clarified changes in participants' pedagogical thinking after the formative intervention. At the pre-test stage, three types of responses prevailed among participants: general support without specification, digitally dependent adaptation, and repeated explanation without changing the mode of presentation.

The first type included responses in which the participant recognized the need for support but did not describe a specific pedagogical action. Examples included: "explain it more simply," "give an easier task," "help individually," or "pay more attention." Such responses demonstrated a positive pedagogical attitude, but did not provide grounds for speaking about a developed capacity for personalization. They did not show exactly how the teacher identifies the difficulty, what is changed in the task, which resources are used, or how the adaptation result is checked.

The second type included digitally dependent responses. Participants proposed using online videos, interactive exercises, tests, learning platforms, presentations, or searching for additional material on the Internet. These solutions could be pedagogically appropriate under conditions of stable access to digital resources, but they did not align with the study's conditions, in which Internet access was unstable or absent. Their presence indicated that some future teachers equated personalization with selecting a digital resource rather than with adapting pedagogical practice itself.

The third type included responses in which participants proposed repeating the explanation without changing its structure. Examples included: "explain once again," "show an example," "solve it together," or "give a similar task." Such decisions could be useful, but they did not always take the nature of the difficulty into account. If a learner does not understand symbolic notation, repeating the same explanation does not remove the barrier. If the problem is related to reading the task condition, linguistic or visual adaptation is needed. If the difficulty is caused by pace, the action needs to be structured into shorter steps.

After the training, the number of responses classified as specific offline adaptations increased. Participants proposed using coloured cards with formulas, number lines, geometric models, diagrams on the board, tables of intermediate steps, paper-based hints, tasks with different numbers of steps, object-based models of fractions, and markers to highlight identical elements in expressions. The responses became more didactically specific. For example, for a learner with dyslexia studying formulas for the square of a binomial and related identities, participants proposed presenting each formula on a separate card, using a large font, dividing the formula into parts with color, saying it aloud, and connecting symbolic notation with geometric interpretation.

The change in responses concerning dyscalculia was especially indicative. At the pre-test stage, participants often wrote that the learner needed to "do more practice tasks" or "have the material explained more slowly." At the post-test stage, more object-oriented solutions appeared in participants' responses: using a number line, cards with intermediate results, magnetic fractions, dividing calculations into sequential micro-steps, allowing the learner to physically rearrange elements of an expression, and showing a proportion through a diagram or table. Such responses indicate a better understanding that personalization requires not only reducing complexity but also changing how content is accessed.

The emotional and communicative component also changed. At the pre-test stage, emotional support was often formal or not mentioned at all. After the training, participants more often noted the need to support the learner without evaluative pressure, to give them the right to make mistakes, to offer a choice of working methods, and to ask clarifying questions without showing irritation. In the video fragments, this was manifested in supportive phrases: "It is good that you stopped exactly here; now we can see which step needs clarification," "We can try another way," "Choose what is more convenient for you: through a diagram or through an example," and "This is not an error in the whole solution, but only one step that we will now correct." Such statements are important because personalization in inclusive education is not limited to selecting a task; it also supports the learner's sense of safety and learning capability.

4. Results of Creating an Individual Learning Route

Creating an individual learning route enabled assessment of the planning component of personalization capacity. Participants had to propose a sequence of actions for a learner with a specific learning profile, taking into account their difficulties, pace, mode of perceiving material, and limited digital access.

At the pre-test stage, typical routes were short and insufficiently specific. Participants often limited themselves to general stages: "review the topic," "give simpler tasks," "check knowledge," "explain once again," or "give homework." In such routes, the connection between the described learner difficulty and the proposed adaptation was rarely visible. For example, if the profile indicated reading impairment or difficulties with concentration, participants did not always change the instructional format, the amount of text, the visual structure of the task, or the form of feedback.

After the formative intervention, participants' routes became more structured. They more often included three interconnected parts: diagnostic, adaptive, and control-oriented. At the first stage, participants proposed identifying the exact type of difficulty the learner had: misunderstanding a concept, an algorithmic error, difficulty understanding the task condition, an excessively fast pace, or difficulty transferring knowledge to a new situation. At the second stage, they selected adapted tasks: cards with different numbers of steps, diagrams, shortened instructions, examples with visual support, and alternative explanations through a drawing or object-based model. At the third stage, they determined a method of checking: a short oral explanation by the learner of their own step, completion of a similar task, filling in a mini-table, or self-checking using a paper-based algorithm.

The logic of feedback also changed. Whereas at the pre-test stage it was often described as "checking the work" or "explaining mistakes," at the post-test stage, formulations oriented toward supporting autonomy appeared more often: “allow the learner to choose one of two cards,” “ask the learner to mark the step that was the most difficult,” “compare two methods of solution,” and “give a short oral hint instead of a ready-made answer.” This indicates the development not only of the adaptive component, but also of the reflective component of personalization.

5. Integration of Quantitative and Qualitative Results

The overall results of the pilot study provide grounds to state that, after the specially organized training aimed at offline-oriented personalization of learning, participants demonstrated positive dynamics in their capacity to act in inclusive situations under conditions of unstable or absent Internet access. The most pronounced changes were observed through two tools: paper-based cases and the video rubric. This is important because these tools measured different but related manifestations of the capacity for personalization: written analysis of a situation and real pedagogical behavior.

The quantitative results showed a substantial increase: the mean score increased by 9.00 points for paper-based cases and by 5.29 points for the video rubric. For both tools, the changes were statistically significant. Since the study used a one-group pilot design, these results should be interpreted as a preliminary confirmation of the positive dynamics associated with the formative intervention, rather than definitive evidence of the training's effectiveness. Further verification requires a control group, a larger sample, and replication of the study in other STEM disciplines.

The qualitative analysis explains the content of this dynamic. After the training, participants did not simply obtain higher scores; they began to conceptualize the pedagogical situation differently. Their responses became more specific, less dependent on digital tools, and more oriented toward the nature of the learning difficulty. They more often distinguished between a problem with reading an instruction, a problem with understanding a mathematical concept, a problem with pace, a problem with attention, or emotional uncertainty. This is an important sign of the formation of the capacity for personalization, since pedagogical adaptation begins with a more precise understanding of the learner's needs.

The results also showed that offline conditions can serve as a productive diagnostic environment. They reveal whether a future teacher can act without a ready-made digital resource. If, in the absence of Internet access, a participant continues to propose only online solutions, this indicates a superficial understanding of personalization. If they can use the board, a diagram, an object-based model, a paper card, an oral hint, a changed pace, or another form of feedback, then one can speak of more stable pedagogical readiness. In this sense, the fully offline format functioned not only as a technical limitation but also as a way to reveal the depth of professional action.

It is also important that the greatest changes in the video rubric results concerned the variability of explanation and adaptation of pace. These criteria are especially indicative of STEM education. In mathematics or computer science, repeating the same explanation often does not help if the learner does not understand the way the content is represented. It is necessary to move from symbolic notation to a diagram, from a diagram to an object-based model, from a complete algorithm to separate steps, and from an abstract example to a familiar situation. Similarly, the pace of learning cannot be the same for everyone: some learners need pauses, repetition, and intermediate checking; others can work faster and need increased complexity. The growth of these particular indicators demonstrates the development of future teachers' methodological flexibility.

A less pronounced but also significant increase was recorded in the criterion of using offline resources. This indicates that future teachers began to better recognize the didactic potential of simple tools: paper, the board, color, cards, diagrams, and object-based models. For STEM education, this is particularly significant, since many complex concepts can be made more accessible through visualization and materialization. Formulas for the square of a binomial and related identities can be explained through area, fractions through parts of a whole, equations through a balance model, proportions through tables of ratios, and algorithms through a sequence of cards. Such solutions do not require the

Internet, but they do require pedagogical imagination and subject-methodological accuracy.

Emotional support also increased, although its initial level was higher than the variability in explaining or adapting pace. This can be explained by the fact that future teachers generally recognized the need for friendly communication, but did not always connect emotional support with the personalization of learning. After the training, support became more functional: it was not limited to general encouragement, but helped the learner understand their own error, choose a way of working, maintain confidence, and continue the activity.

The obtained results are pilot in nature, but they provide grounds for an important intermediate conclusion: the capacity for personalizing learning can and should be developed through specially organized pedagogical situations in which the future teacher encounters real limitations, inclusive needs, and the necessity of making rapid methodological decisions. The most effective tasks were those that required not the reproduction of theoretical provisions, but action: recognizing a difficulty, changing an explanation, adapting material, using an available resource, and supporting the learner. These actions constitute the practical core of personalization of learning in inclusive STEM education under conditions of unstable Internet access.

Discussion

The obtained results, with regard to the pilot one-group design, provide grounds for preliminarily considering pre-service STEM teachers' capacity for personalization of learning not as a separate technical skill, but as an integrated professional quality formed at the intersection of methodological training, inclusive pedagogy, digital competence, emotional sensitivity, and readiness to act under limited resources. The most important result of the pilot study is not only the increase in quantitative indicators after the formative intervention, but also the change in the nature of future teachers' pedagogical decisions. After the training, they more often moved from general recommendations to specific actions: they diagnosed the type of difficulty, adapted the mode of presenting mathematical material, used paper-based and visual supports, proposed several explanations, adjusted the pace of work, and incorporated emotional support into the very logic of personalization.

This result is consistent with the contemporary understanding of personalized learning in STEM education. Studies devoted to AI-supported personalized STEM education emphasize that digital and adaptive systems can significantly expand opportunities for individualizing trajectories, automatically selecting tasks, and providing feedback (Sun et al., 2025). However, the results of our pilot study show that the core of personalization remains pedagogical rather than technological. Participants began to personalize learning more effectively, not because they gained access to more complex digital tools, but because they learned to identify a specific learning difficulty and select a pedagogical action in response to it. This is important for STEM education, where a learning error is often not accidental but structural: a learner may not understand symbolic notation, the sequence of an algorithm, the meaning of a formula, the logic of transitions, or the way to interpret a graphical model.

In this respect, the study's results complement those of Zhang and Zhang (2024), who emphasize that artificial intelligence in teacher education opens new opportunities to support teaching, inclusive learning, and digital literacy, but requires pedagogical reflection. Our results specify this thesis under conditions of unstable or absent Internet access. If a digital tool is unavailable, personalization should not disappear. It should move into other forms: paper-based individual routes, cards of varying difficulty, diagrams, object-based models, oral hints, and flexible explanations on the board. Thus, the capacity for personalization is more sustainable when the future teacher possesses not only a tool but also the pedagogical principle of its use.

It is indicative that the greatest increase in the video rubric was recorded for the criteria of variability of explanation and adaptation of pace. This demonstrates the development of methodological flexibility. For teaching mathematics and other STEM disciplines, such flexibility is particularly important because the same content may require different modes of presentation: symbolic, graphical, object-based, algorithmic, linguistic, or visual. For example, the formula for the square of a binomial can be explained through algebraic notation, the area of a square, color grouping of elements, cards with separate parts of the expression, or oral articulation of the formula structure. It is the ability to shift quickly among such modes of presentation that distinguishes personalized learning from repeating the same explanation.

This conclusion is consistent with research on differentiated instruction. Samsudi et al. (2024) show that the effectiveness of differentiated instruction depends on the accuracy of assessment of the learning situation, the organization of the differentiated process, and the variability of outcomes. Aguhayon et al. (2023) demonstrate that differentiated instruction in mathematics helps overcome learning gaps and increases learners' confidence. In our study, these provisions received practical confirmation: after the training, future teachers more often proposed not simply an "easier task," but another task structure, another way of explanation, another pace, and another form of support. In other words, differentiation shifted toward personalization, with adaptation built around the specific needs of the learner.

The results can also be explained through the Universal Design for Learning approach. UDL assumes that the diversity of ways to present material, engage in activity, and demonstrate results should be embedded in educational design from the outset, rather than added only when difficulties have already arisen (Chavarría et al., 2023; Ismailov & Chiu, 2022). After the training, participants began to think more precisely along this logic: they did not wait until the learner "failed," but anticipated different ways of accessing the material in advance. In this sense, offline personalization does not contradict UDL, but rather specifies it for conditions of limited digital infrastructure. Multiple means of representation can be implemented not only through video, interactive simulation, or a digital board, but also through a printed diagram, a card, color, an object-based model, an oral algorithm, or a drawing on the board.

At the same time, the data show that before the training, future teachers often equated personalization with a digital resource. The pre-test responses indicated a tendency to propose online videos, electronic exercises, Google Classroom, online tests, or searching for a simpler explanation on the Internet. This does not mean that such solutions are pedagogically incorrect. They may be appropriate under stable technical conditions. The problem lies elsewhere: if personalization depends only on digital access, it becomes unstable. In an Internet or electricity outage, the teacher loses not only the tool but also the very mode of pedagogical action. That is why the offline conditions in our study served as a pedagogical stress test: they revealed whether the participant had developed an internal logic of personalization independent of a specific platform.

This conclusion correlates with studies on teachers' digital competence. Gómez-Pablos et al. (2022) and Mattar et al. (2022) emphasize that digital competence is not reduced to technical mastery of tools. It includes pedagogically appropriate use of technologies, ethical responsibility, safety, work with information, and the ability to integrate digital tools into the educational process. Our study allows one more aspect to be added: the digital competence of a pre-service STEM teacher should include the ability to preserve pedagogical action under conditions of technical instability. Otherwise, digital competence risks becoming a narrow instrumental skill that works only under favorable conditions.

This point is especially important for the Ukrainian educational environment, where unstable Internet access, power outages, blended learning, asynchronous interaction, and learning under security restrictions have become part of the pedagogical reality. The study by Ofosu-Asare (2024) shows that, under conditions of limited access to computers and the Internet, effective ICT methodologies should rely on available resources, local pedagogical solutions, and teachers' professional preparation. Okoye et al. (2022) also emphasize that the lack of infrastructure and uneven Internet access remain serious barriers to the use of digital technologies in learning. Our results confirm that pre-service STEM teacher training should include not only the mastery of digital services but also the formation of offline-ready methodological scenarios.

In this regard, our findings complement previous Ukrainian studies on the use of digital technologies in the training of future teachers of mathematics and computer science. In the study by Semenikhina et al. (2022), a STEM project is considered as a means of teaching modeling to future teachers of mathematics and computer science. What is important in this approach is that a STEM project develops the ability to see a learning task as an open situation in which one needs to select a model, a tool, a mode of representation, and a logic of explanation. This project-modeling logic is close to personalization: the future teacher must not reproduce a ready-made algorithm, but construct an appropriate pedagogical model for a specific learner.

The study by Shyshenko et al. (2022), which prepared a mathematics teacher to create a maker space in mathematics lessons using GeoGebra, is also conceptually close to the problem addressed in this chapter. A maker space in mathematics education involves active construction, inquiry, visualization, model creation, work with objects, and variability of pathways to knowledge. Although GeoGebra is a digital tool, the pedagogical idea of a maker space is not limited to its use. It consists of creating an environment where the learner can act, try, change the model, and see the connection between an abstract concept and its visual or object-based representation. In our study, this logic is transferred to offline conditions: even without GeoGebra, the teacher can support a "maker approach" through paper-based models, cards, diagrams, manipulatives, the board, and color.

A similar connection can be traced to the study by Shyshenko et al. (2023), which examines the implementation of a facilitative approach to teaching mathematical disciplines to future mathematics teachers using the Maple software package. The facilitative approach is important because it shifts the teacher's role from transmitter of knowledge to organizer of cognitive activity, consultant, and partner in solving a learning problem. In our study, the development of the capacity for personalization also implied a facilitative shift in the future teacher's position: they had to provide not only the correct explanation but also help the learner find an accessible way to understand. This was especially noticeable in the video fragments, where, after the training, participants more often asked clarifying questions, offered a choice of working methods, broke the task into steps, and supported the learner when difficulties arose.

The study by Drushlyak et al. (2023), devoted to the effectiveness of digital technologies in inclusive learning for teacher training, is directly related to the issues addressed in this chapter. The authors show that digital technologies can be productive for inclusive learning when methodologically justified and aligned with the preparation of future teachers to work with diverse educational needs. Our study does not deny the effectiveness of digital technologies. On the contrary, it clarifies the condition of their pedagogical productivity: the future teacher must understand the inclusive logic of adaptation regardless of whether they have access to a digital tool at a particular moment. In this sense, offline personalization is not an alternative to digital inclusion, but its necessary complement.

The results of the study also resonate with the work of Yurchenko et al. (2023), which considers the individual educational trajectory a successful skill for teachers in the digital age. Building an individual educational trajectory requires the teacher to see the learner's needs, determine the sequence of learning steps, select resources, adjust the route, and support progress. In our study, the task of creating an individual learning route essentially tested this capacity on a micro scale. After the training, the routes created by participants became more structured, including a diagnostic stage, adapted tasks, alternative explanations, feedback, and offline resources. This indicates that an individual educational trajectory should be formed not only in the digital environment, but also in the pedagogical thinking of the teacher.

The emotional component of personalization requires particular attention. In our study, emotional support was one of the criteria of the video rubric, and after the training, its indicator increased. This is important because, in inclusive STEM learning, difficulties often have not only a cognitive but also an emotional dimension. A learner may know part of the algorithm but fear making a mistake; may understand the idea but fail to keep pace; or may avoid answering because of previous negative experience. Calandri et al. (2025) emphasize that teachers' emotional competence affects learners' engagement, motivation, and academic outcomes in inclusive learning. In our study, this was manifested in participants' tendency not only to adapt the task but also to change communication: they supported the right to make mistakes, offered choice, marked partial success, and helped the learner maintain confidence.

In this regard, the study by Shyshenko et al. (2024), which examines the use of digital technologies in the study of mathematical analysis as a basis for developing learners' emotional intelligence under new crisis conditions, is indicative. This study is important for our discussion for two reasons. First, it shows that digital technologies in mathematics education can support not only cognitive but also emotional development. Second, it actualizes crisis conditions as a factor that changes the requirements for pedagogical interaction. Our study continues this line, but shifts the focus to the future teacher: they must be able to support the learner emotionally and methodologically, even when digital resources are limited.

The study by Henriksen et al. (2025) also supports this conclusion, as the authors view socio-emotional learning and generative AI in teacher education as interrelated but not interchangeable dimensions. Technology can help the teacher, but it does not replace empathy, pedagogical tact, and the ability to support the learner's autonomy and competence. In our study, this became evident in fully offline situations: it was precisely the future teacher's emotional and pedagogical presence that determined whether the "learner" perceived difficulty as failure or as part of learning work.

The connection between the obtained results and the problem of mathematical literacy is also important. In the study by Shyshenko et al. (2025), the influence of digital media on the development of mathematical literacy and the possibilities of service-learning are examined. Mathematical literacy involves the ability to use mathematical knowledge in real-life situations, interpret data, models, and dependencies, and justify decisions. Personalized learning in this sense is one way to support mathematical literacy, as it enables learners with different needs to access the content and its practical applications. If the teacher can adapt an explanation, model, or task, they do not lower expectations, but open another pathway to the same substantive outcome.

The obtained results also confirm the significance of active, project-based, and practice-oriented learning in the training of future teachers. Doolittle et al. (2023) show that active learning involves learners in activities that require analysis, application, evaluation, and creation. Rehman et al. (2024) demonstrate the effectiveness of project-based learning in developing twenty-first-century skills and fostering engagement in the mathematics classroom. In our study, the formative training was structured as follows: participants not only listened to information about personalization but also analyzed cases, created cards, modeled a lesson, reviewed video recordings, and reflected on their own actions. This may explain the positive dynamics recorded after the formative intervention, especially in behavioral indicators.

The results also support the conclusions of Donath et al. (2023), who, in a meta-analysis of professional development for inclusive education, found that knowledge changes more easily than actual pedagogical behavior. In our study, the recorded changes were most visible where participants had to act, receive feedback, and adjust their own decisions. This provides grounds to argue that lecture-based or theoretical study of the topic is insufficient for developing the capacity for personalization. Practical training situations are needed if the aim is not only to increase awareness, but also to change pedagogical behavior.

At the same time, the results require cautious interpretation. The study had a pilot one-group design, the sample was small, and the participants were mainly future mathematics teachers. The absence of a control group prevents fully separating the influence of the training from other factors, including the effects of repeated testing, participants' general learning experience, and their increased attention to the problem of personalization after the pre-test. In addition, the offline situations were simulated rather than fully natural. They reproduced typical difficulties of the educational process under conditions of unstable Internet access, but did not cover all factors of real pedagogical practice: prolonged stress, a multilevel classroom, simultaneous work with many learners, time constraints, parental expectations, or administrative requirements. Further studies should test the proposed approach with larger samples, control groups, across different STEM disciplines, and in real pedagogical practice.

A separate methodological issue is the diagnosis of personalization capacity. Our results show that the combination of paper-based cases, an individual route, and video modeling provides a much fuller understanding of future teachers' preparedness than a single test or self-assessment. Cases reveal analytical capacity, the route reveals planning capacity, and the video recording reveals behavioral capacity. Such multicomponent diagnostics correspond to the complex nature of personalization as a soft skill. At the same time, future work should strengthen the toolkit's reliability by involving multiple experts, verifying inter-rater agreement, clarifying level descriptors, and developing scales for different STEM subjects and educational needs categories.

Overall, the study's results allow for broader theoretical generalization. In the training of pre-service STEM teacher s, personalization should be considered not as an auxiliary pedagogical technique, but as a foundation of professional readiness for an inclusive educational process. This readiness means the teacher can operate in different technological modes: on digital platforms, in blended learning, asynchronously, with limited Internet access, or in complete offline mode. Such multi-modality is a sign of mature professional training. It does not oppose digital and offline learning, but combines them around the main pedagogical purpose: ensuring the learner's access to content, activities, feedback, and support.

Thus, the discussion of the results shows that short-term training in offline-oriented personalization contributed not only to the development of separate adaptation techniques among future teachers but also to more holistic pedagogical thinking. After the training, participants better recognized difficulties, selected more accurate modes of explanation, used available materials more actively, adapted the pace more often, and demonstrated more supportive communication. In comparison with previous studies, this provides grounds to argue that effective preparation of a STEM teacher for inclusive education should combine digital technologies, modeling practices, a facilitative approach, emotional support, and offline-ready methodological solutions. It is precisely this integration that ensures the sustainability of personalized learning amid educational instability.

Conclusions

The study clarified the content of pre-service STEM teachers' capacity for personalizing learning in inclusive education under conditions of unstable or absent Internet access. In this chapter, this capacity was considered neither a separate technical skill nor the ability to use an adaptive platform, but rather an integrated soft skill of the future teacher. It combines methodological flexibility, diagnosis of individual learning difficulties, adaptation of STEM content, variability of explanation, support for different paces of work, inclusive sensitivity, emotional support, and digital-pedagogical maturity.

The theoretical analysis showed that personalized learning in STEM education is increasingly supported by digital technologies, learning analytics, and artificial intelligence tools. However, these tools do not eliminate the teacher's role. On the contrary, they increase the requirements for the teacher's professional judgment, ethical responsibility, and ability to assess the pedagogical appropriateness of technology. In situations of unstable Internet access, this becomes especially visible: personalization based only on the selection of an online resource loses its stability, whereas personalization based on the pedagogical logic of adaptation can be maintained through paper-based routes, cards, diagrams, object-based models, the board, oral hints, adjusted pace, and supportive communication.

The study identified three interrelated components of the capacity for personalization of learning: diagnosis of individual learning difficulties, adaptation of STEM content, and organization of offline differentiation. The first component concerns the ability to determine exactly where a learning barrier arises: while reading the task condition, understanding a concept, performing an algorithm, interpreting symbolic notation, transferring knowledge, or maintaining attention. The second component includes changing the mode of presenting material through visual, object-based, linguistic, or algorithmic supports. The third component concerns the ability to provide individualized support when online platforms, digital tests, videos, or interactive environments are unavailable.

The empirical part, organized as a pilot one-group study, showed positive dynamics after a short-term practice-oriented training program. In the paper-based cases, the mean score increased from 8.42 to 17.42 points, and according to the video rubric, from 3.03 to 8.32 points. Statistical verification confirmed the significance of the changes for both tools. Given the absence of a control group, these results should be interpreted with caution: they indicate positive dynamics after the formative intervention, but require further verification in broader quasi-experimental or experimental studies.

The qualitative analysis showed that the changes concerned not only quantitative indicators, but also the nature of participants' pedagogical thinking. At the beginning of the study, a significant proportion of responses were general or digitally dependent. After the training, participants more often proposed specific offline adaptations: number lines, paper-based cards, diagrams on the board, step tables, color-coded formulas, object-based models, geometric interpretations, oral articulation of an algorithm, and individual mini-routes. This indicates a transition from the general intention to help to the capacity to design a specific pedagogical action according to the learner's educational needs.

Video modeling confirmed that the capacity for personalization is most clearly manifested in behavioral situations. A simulated lesson fragment allows the future teacher to see whether they can notice when a learner stops, ask a clarifying question, change the mode of explanation, adapt the pace, use an available offline resource, and provide emotional support. The combination of paper-based cases, an individual learning route, and a video rubric forms a diagnostic complex suitable for assessing the analytical, planning, and behavioral components of this soft skill.

Offline conditions in the study functioned not only as a technical limitation but also as a diagnostic environment. They showed the extent to which personalization is an internally assimilated pedagogical logic, rather than merely a reaction to the availability of a digital tool. With full Internet access, a future teacher can address methodological uncertainty with a ready-made video, an online test, or a digital exercise. Without Internet access, such compensation is impossible, and the real capacity to adapt content, explanation, pace, and communication independently becomes visible.

The practical significance of the results lies in the potential to use the proposed approach in the methodological training of pre-service teachers of mathematics, computer science, and other STEM disciplines. It is advisable to include in relevant courses cases with inclusive situations under unstable Internet access, tasks for adapting mathematical text, creation of paper-based personalized cards, modeling lessons without digital resources, analysis of video fragments of pedagogical interaction, and design of individual learning routes in paper-based and blended formats. Such tasks should not replace digital training but complement it by building the capacity to transfer the pedagogical idea of personalization across different technological conditions.

Further research should focus on testing the proposed approach with larger samples, control groups, across different STEM specialties, and in real pedagogical practice. The diagnostic toolkit also needs further development: it is necessary to verify inter-rater agreement in the evaluation of video recordings, clarify rubrics for different categories of special educational needs, and develop separate cases for computer science, physics, natural sciences, technical creativity, and STEM projects. It is also promising to study the long-term effects of the training and the relationships among capacity for offline personalization, digital competence, AI literacy, emotional competence, and readiness for inclusive education.

Thus, pre-service STEM teachers' capacity to personalize learning under conditions of unstable Internet access is an important component of their professional training. It ensures the sustainability of pedagogical action, supports the inclusiveness of the educational process under limited resources, and helps preserve the accessibility of STEM content for learners with different needs. Such training enables the future teacher to act professionally not only when digital conditions are favorable, but also when the quality of learning depends primarily on their pedagogical flexibility, attentiveness, and capacity to support learners in specific learning situations.

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Chapter 4.
EMOTIONAL INTELLIGENCE OF PRE-SERVICE STEM TEACHERS AS A CONDITION FOR INCLUSIVE INTERACTION IN A DIGITALLY UNSTABLE EDUCATIONAL ENVIRONMENT

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Abstract. *The chapter substantiates the significance of pre-service STEM teachers' emotional intelligence as a condition for inclusive pedagogical interaction in a digitally unstable educational environment. The problem is relevant because contemporary professional training of teachers of science, mathematics, and technology-related disciplines requires integrating subject-specific, methodological, digital, inclusive, and emotionally communicative readiness. In a digital environment, pedagogical interaction is complicated by technical failures, unstable connectivity, loss of video or audio channels, and platform delays, which are especially noticeable for learners with special educational needs. The purpose of the study was to theoretically substantiate the role of pre-service STEM teachers' emotional intelligence in organizing inclusive interaction and to analyze the results of a pilot evaluation of the training program "Emotional Intelligence for Inclusive STEM." The research methodology combined analysis of scholarly sources, a pilot "pre-test - formative intervention - post-test" design, the test "Recognition of Emotions in a Digital Environment," and a scenario-based case that modeled the sudden loss of video connection during interaction with a learner with a hearing impairment. The study involved 36 pre-service teachers of physics, mathematics, and computer science. The results showed a statistically significant increase in the ability to recognize emotions in a digital environment, with the mean score rising from 65.08% to 74.11%. Even more pronounced positive dynamics were identified in the scenario-based case: the mean expert evaluation score increased from 5.47 to 10.67 points. The obtained data indicate that training, case-based, and reflective tasks may contribute to the development of emotional perception, empathy, self-regulation, and inclusive communicative flexibility among pre-service STEM teachers. Prospects for further research include expanding the sample, including a control group,*

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conducting delayed measurement, and developing a broader set of inclusive digital cases.

***Keywords**: emotional intelligence; pre-service STEM teachers; inclusive education; digital instability; digital educational environment; pedagogical interaction; soft skills; self-regulation; scenario-based case; professional training.*

Introduction

The training of pre-service STEM teachers today requires reconsideration not only of the content of professional and methodological competencies, but also of the personal and professional qualities that ensure pedagogical interaction under conditions of uncertainty, diverse educational needs, and instability in the digital environment. Traditionally, STEM education is associated with the development of logical thinking, experimental culture, modeling skills, data work, the use of digital tools, and the solving of complex problems. However, pedagogical practice shows that effective teaching of science, mathematics, and technology-related disciplines depends not only on the teacher's subject-specific preparation. To a comparable extent, it is also connected with the teacher's ability to recognize learners' emotional states, support them in situations of cognitive tension, prevent communicative barriers, reduce anxiety, and create an atmosphere in which the complexity of STEM content does not become a psychological obstacle.

This problem becomes particularly acute in an inclusive educational environment. Learners with special educational needs may perceive information differently, respond at different paces, have specific communicative needs, and be more sensitive to changes in the organization of a lesson or a digital interface. Under such conditions, the teacher's professional action is not limited to explaining the learning material or selecting adapted tasks. It includes the ability to notice the learner's emotional response, change the mode of communication in a timely manner, avoid stigmatizing language, and support the child or young person's participation in the shared activity. In this case, emotional intelligence appears not as an additional personal characteristic, but as a component of professional readiness for pedagogical interaction.

In scholarly literature, teachers' emotional intelligence is defined as the ability to understand and regulate their own emotions, recognize the emotions of others, show empathy, and build constructive social relationships. In pedagogical activity, these characteristics have practical significance because they influence the nature of interaction between the teacher and learners, the level of learning motivation, the psychological climate in the group, and participants' readiness to cooperate in the educational process. Empirical studies confirm the relationships among teachers' emotional intelligence, learners' motivation for academic learning, and the quality of interpersonal relationships in the learning group (Rahman et al., 2024). Integrative reviews of teachers' psychological characteristics show that emotional competence, engagement, attentiveness to psycho-emotional states, and self-regulation are associated with teaching effectiveness, professional well-being, and teachers' resilience to burnout (Bardach et al., 2021).

For a pre-service STEM teacher, emotional intelligence has specific significance. STEM subjects are often perceived by learners as complex, formalized, and requiring a high level of abstract thinking, the ability to work with errors, and the capacity to sustain intellectual effort. Under such conditions, the teacher must not only explain content, but also regulate the emotional dynamics of the lesson. The teacher must notice frustration, fatigue, fear of making mistakes, decreased confidence, and avoidance of participation in discussion. For learners with special educational needs, these difficulties may be intensified by additional barriers to perception, communication, or social interaction. Therefore, the development of pre-service STEM teachers' emotional intelligence should be considered part of their professional preparation for working with diverse educational trajectories, rather than merely an element of general soft skills development.

The digital educational environment, in which pre-service teachers are increasingly trained and school STEM education is increasingly implemented, requires separate attention. Digital technologies expand opportunities for access to learning materials, visualization of complex concepts, process modeling, organization of feedback, and personalization of learning. In inclusive education, they may serve a compensatory function by supporting alternative ways of presenting information, providing captions, using interactive tasks, enabling asynchronous communication, and adapting the pace of learning. Systematic reviews show that digital tools and specialized technologies can enhance the accessibility of education for learners with diverse needs when integrated in a pedagogically meaningful way (Navas-Bonilla et al., 2025).

At the same time, the digital environment is not a neutral or always stable space. Technical failures, unstable Internet connections, power outages, platform changes, delays in learning management systems, and loss of audio or video channels can sharply alter the course of a lesson. For inclusive interaction, such situations are especially significant. For example, the loss of video connection may deprive a learner with a hearing impairment of access to visual signals or captions. A delay in the chat may complicate participation for those who use written communication as their main channel of interaction. A sudden change of platform may cause disorientation among individuals who need a predictable structure of the educational environment. In such situations, the teacher must act simultaneously in several dimensions: technical, methodological, communicative, and emotional.

This is why the concept of digital instability in this study is considered not only a technical characteristic of the educational environment but also a pedagogically significant condition that affects the quality of interaction. Digital instability reveals the extent to which a pre-service teacher can maintain a professional stance in a failure situation, support the learner, quickly change the communication channel, and explain further actions without increasing anxiety or the feeling of exclusion. In this understanding, emotional intelligence performs a regulatory function. It helps the teacher not only control their own tension, but also recognize the emotional consequences of a technical problem for participants in the educational process.

Preparing pre-service teachers for such activity requires specially organized pedagogical conditions. It is not enough merely to declare the importance of emotional competence or include it in the list of desirable graduate qualities. Learning situations are needed in which a pre-service teacher can analyze their own emotional reactions, practice recognizing emotions from incomplete digital signals, rehearse methods of empathetic communication, model actions in the face of technical failures, receive feedback, and engage in reflection. Training, case-based, and reflective methods make it possible to move emotional intelligence from the plane of general personal development to that of professional pedagogical action.

The need for this approach is consistent with research on teachers' professional development in the digital age. Contemporary studies emphasize that teachers' digital competence should be developed alongside pedagogical, social, and personal competencies, as the use of technology alone does not guarantee high-quality interaction (Gómez-Pablos et al., 2022). Research on the implementation of digital technologies in education also shows that sustainable changes in pedagogical practice require not one-time instructions, but systematic professional support, practical exercises, mentoring, and reflection (Amemasor et al., 2025). For the preparation of pre-service STEM teachers, this means the need to create educational situations in which digital tools, inclusive pedagogy, and emotional self-regulation are not considered separately, but are combined in a single professional action.

The problem is also connected with the development of artificial intelligence and the broader field of pre-service teachers' digital literacy. AI literacy and digital literacy are increasingly described not only in terms of technical knowledge but also in terms of ethical, behavioral, cognitive, and affective components. In particular, preparing pre-service teachers to use digital and AI tools involves understanding their possibilities, limitations, risks of bias, influence on pedagogical roles, and impact on the nature of interaction with learners (Ayanwale et al., 2024; Ng et al., 2023). In this sense, emotional intelligence is not opposed to digital competence. On the contrary, it helps pre-service teachers use digital tools responsibly while paying attention to the human dimension of education.

Within inclusive STEM education, this integration becomes especially important. The teacher has to work with abstract and often complex content, digital simulations, visualizations, platforms, online communication, different paces of mastering material, and the diverse educational needs of learners. If digital instability is added to this, the pedagogical situation becomes multilayered. A technical failure may result in the loss of part of the learning content, but it can have an even greater impact on learners' sense of safety, engagement, and acceptance. Therefore, the pre-service teacher must be able to quickly reorient educational interaction without losing attention to learners' emotional states.

Despite the considerable body of research on teachers' emotional intelligence, digital competence, inclusive education, and STEM teacher preparation, the intersection of these areas remains insufficiently studied. Most often, these areas are analyzed separately: emotional intelligence as a psychological characteristic of the teacher; digital competence as technological readiness; inclusive education as a system of adaptations and support; and STEM education as a content-methodological field. At the same time, the real professional action of a pre-service teacher combines all these components. It is in a specific pedagogical situation, for example, during an online STEM lesson when the video connection with a learner with special educational needs disappears, that it becomes clear that subject-specific, digital, inclusive, and emotional readiness cannot be separated.

In this chapter of the monograph, the emotional intelligence of pre-service STEM teachers is considered as a condition for inclusive pedagogical interaction in a digitally unstable educational environment. This approach allows combining theoretical analysis with the results of a pilot study aimed at identifying the dynamics of selected emotional intelligence indicators following a specially organized training program. Particular attention is paid to pre-service teachers' ability to recognize emotions in a digital environment and to their actions in a scenario-based case that models inclusive interaction under conditions of technical failure. This logic makes it possible not only to describe the results of empirical measurement, but also to show their significance for the content of professional training for pre-service STEM teachers.

Thus, the study's relevance lies in the contradiction between the growing expectations for the pre-service STEM teacher as a professional capable of working in digital and inclusive educational environments and the insufficient development of pedagogical approaches to the purposeful cultivation of emotional intelligence, particularly under conditions of digital instability. Addressing this contradiction requires a theoretical understanding of emotional intelligence as a professional resource for teachers, the development of appropriate diagnostic tools, and the evaluation of training approaches oriented toward realistic situations of inclusive digital interaction.

Literature Review

The problem of developing emotional intelligence in pre-service STEM teachers lies at the intersection of several research areas: teacher professional development, inclusive education, the digital transformation of the educational environment, the development of soft skills, and the methodology of teaching science, mathematics, and technology-related disciplines. In contemporary studies, these areas are often analyzed separately. Emotional intelligence is considered primarily a psychological characteristic of teachers; digital competence is the ability to use technologies effectively; inclusive education is a system of organizational, methodological, and communicative adaptations; and STEM education is a field oriented toward integrating science, technology, engineering, and mathematics. At the same time, the real professional activity of a pre-service teacher requires the combination of these components. The teacher must not only explain complex content, select digital tools, and organize learning activities, but also support learners in situations of uncertainty, cognitive tension, technical failures, emotional exhaustion, or communicative difficulties.

In scholarly literature, teachers’ emotional intelligence is typically described as the ability to understand one's own emotions, recognize others' emotions, regulate emotional reactions, show empathy, and build constructive social relationships. For pedagogical activity, these abilities have not only general psychological but also practical significance. They affect the nature of interaction between the teacher and learners, the quality of feedback, the level of learning motivation, the emotional climate in the group, and learners’ readiness to participate in shared activity. Rahman et al. (2024) demonstrate that teachers' emotional intelligence is related to learners' motivation for academic learning. The authors rely on five dimensions closely aligned with D. Goleman's model: self-awareness, self-regulation, self-motivation, empathy, and social skills. This approach makes it possible to consider emotional intelligence as a professionally significant characteristic manifested in specific pedagogical decisions.

A broader view of the significance of teachers' psychological characteristics is presented in the integrative review by Bardach et al. (2021). The researchers summarize empirical data on the relationships among teachers' psychological characteristics, teaching effectiveness, professional well-being, retention in the profession, and the quality of interpersonal relationships. In this approach, emotional intelligence is not isolated from other components of teachers' professional functioning. It is connected with work engagement, attentiveness to one's own psycho-emotional state, professional motivation, and the ability to maintain positive relationships with different participants in the educational process. This is especially important for the training of pre-service STEM teachers, since teaching science and mathematics is often accompanied by fear of error, frustration, decreased confidence, and a need for support when solving complex tasks.

In STEM education, emotional intelligence takes on particular significance. STEM disciplines involve work with abstract concepts, formal models, algorithms, experimental data, digital simulations, and complex problem situations. For some learners, such an activity may be associated with tension, uncertainty, or a tendency to avoid participation. Ayeni et al. (2024) emphasize that emotional intelligence and counseling techniques can strengthen STEM education by helping learners develop resilience, focus, interpersonal skills, and motivation. This provides grounds for considering the emotional intelligence of a pre-service STEM teacher as a resource for overcoming not only communicative, but also learning and cognitive difficulties.

A separate direction of contemporary research concerns teachers' emotional competence in inclusive education. Calandri et al. (2025) found, in a systematic review, that teachers' emotional competence includes emotional intelligence, emotional awareness, empathy, and emotion regulation. These components influence learner engagement, motivation, emotional self-regulation, emotional development, and educational outcomes. The authors also emphasize that the significance of emotional competence may vary depending on learners' developmental characteristics, educational needs, and communicative capacities. Thus, in inclusive education, teachers' emotional intelligence performs not only a regulatory but also a supportive function. It helps the teacher notice difficulties that are not always immediately evident in learning outcomes.

Inclusive pedagogical interaction requires the teacher to work with different ways of perceiving information, different paces of involvement in the educational process, and different communicative needs. In a traditional classroom environment, the teacher can rely on a wide range of signals, including facial expressions, gestures, eye contact, group responses, and behavioral manifestations. In a digital environment, these signals often become incomplete or distorted. Video may be turned off, sound may be interrupted, chat may experience delays, and parts of the interaction may move to an asynchronous format. For learners with special educational needs, this creates additional risks. Loss of the video channel may complicate communication for a learner with a hearing impairment; a sudden change of platform may cause disorientation in a learner who needs a stable structure; and a delayed response may increase anxiety or a sense of isolation.

Technologies can support inclusive education, but their impact depends on how they are used pedagogically. Navas-Bonilla et al. (2025) found, in a systematic review, that digital tools and specialized devices can enhance learning accessibility for learners with diverse needs. The authors include among these tools mobile devices, interactive applications, augmented reality, adaptive environments, and other instruments that help personalize learning and reduce barriers to participation. However, a digital tool alone does not guarantee inclusive education. If the teacher does not take into account the learner's emotional, communicative, and organizational needs, technology may not strengthen inclusion but instead create new forms of exclusion.

Digital instability is one of the phenomena that most sharply reveals the relationship between teachers' digital competence and their emotional readiness for pedagogical action. In this study, digital instability should be understood as a set of technical, organizational, and psychological disruptions to the normal course of digital interaction: unstable Internet connection, platform failures, power outages, delays in learning management systems, loss of audio or video channels, and the need to quickly change the mode of communication. Such instability is not only a technical problem. It can affect learners' emotional state, disrupt their sense of predictability, reduce engagement, and increase anxiety. For inclusive interaction, this is especially significant because a learner with special educational needs may lose precisely the support channel that enabled their participation in the lesson.

Studies of teachers' digital competence consistently emphasize that contemporary teachers must develop technological and digital competencies together with pedagogical, professional, personal, and social competencies. Gómez-Pablos et al. (2022), in a systematic review, note that a significant proportion of higher education teachers have low or medium-low levels of digital competence in specific areas. Competencies related to assessment, practical use of digital tools, and personalized support for learners remain especially problematic. For pre-service STEM teachers, this issue has dual significance. On the one hand, STEM education actively relies on digital tools, modeling, visualization, and data work. On the other hand, the mere availability of digital tools does not mean that a pre-service teacher is ready for emotionally sensitive and inclusive interaction in a digital environment.

Arif et al. (2025) emphasize that teachers' competence in the digital age cannot be reduced to proficiency in individual programs or platforms. It involves creating educational environments that support collaboration, creativity, critical thinking, and learners' responsible participation. A similar conclusion is reached by Amemasor et al. (2025), who, in a systematic review of teachers' professional development for digital integration, show the importance of practical learning, mentoring, institutional support, and sustained professional guidance. For our study, this is important because the development of pre-service STEM teachers' emotional intelligence cannot be reduced to a brief theoretical introduction to concepts such as empathy or self-regulation. Scenario-based tasks, training exercises, modeling of real difficulties, reflection, and feedback are needed.

The issue of digital transformation in teacher education has recently become increasingly linked to the development of artificial intelligence. Zhang and Zhang (2024) examine the use of AI in teacher education across several dimensions: teaching support, the creation of an inclusive educational environment, the development of digital literacy, the personalization of learning, and the strengthening of interaction between teachers and learners. This approach shows that digital and AI tools can expand teachers' capacities, but they do not replace professional judgment. Technology may help adapt materials, analyze learning needs, or organize feedback, but an empathetic decision in an inclusive interaction remains the teacher's responsibility.

This conclusion is consistent with studies of AI literacy among pre-service teachers. Ayanwale et al. (2024) show that a deeper understanding of artificial intelligence is related to readiness to use it, ethical reflection, identification of limitations, and problem-solving. Ng et al. (2023) propose an affective-behavioral-cognitive-ethical framework of AI literacy, in which motivation, confidence, collaboration, and ethical learning are considered together with knowledge and skills. This has direct significance for the training of pre-service STEM teachers, since digital literacy cannot be separated from the teacher's emotional and ethical maturity. In an inclusive interaction, the teacher must not only know which digital tool to use but also understand how that tool will affect the learner's accessibility, autonomy, dignity, and emotional state.

A separate group of studies is devoted to teachers' professional resilience and their ability to act in crisis or unstable conditions. After the COVID-19 pandemic, military and social crises, and the accelerated digitalization of education, attention to the psycho-emotional well-being of teachers and learners has increased. Beardsley et al. (2021) show that the emergency transition to distance learning changed teachers' perceptions of their own digital skills and their motivation to use technologies. At the same time, this experience revealed the need not only for technical training, but also for sustained professional support. Mhlongo et al. (2023) also emphasize that the adoption of smart digital technologies in educational environments is accompanied not only by new opportunities but also by challenges related to accessibility, organizational readiness, interaction quality, and unequal participation.

For pre-service STEM teachers, these findings have applied significance. Their training should include not only mastering digital tools and STEM teaching methodology, but also developing the ability to act in micro-crisis pedagogical situations. Such situations include technical failures during an online lesson, loss of communication with a learner, inability to use a planned digital resource, need to quickly switch to a backup communication channel, asynchronous support for a learner, or a change in how material is explained. In such circumstances, technical awareness alone is not enough; emotional self-regulation is also important. The teacher must remain calm, clearly explain the next steps, support learners, and avoid increasing emotional tension.

In pre-service STEM teacher training, active, experiential, and reflective methods are particularly important. Studies of teachers' professional development in STEM and STEAM education demonstrate the effectiveness of programs that combine content preparation, practical tasks, work with digital tools, mentoring, collaboration, and reflection. Preparing teachers to integrate AI methods into STEM education also requires gradual entry into the content, practical exercises, analysis of ethical issues, and modeling of pedagogical situations (Zhang & Zhang, 2024). This confirms the appropriateness of building formative work not as a separate psychological training detached from professional content, but as a system of professionally oriented tasks in which pre-service teachers simultaneously work with STEM content, the digital environment, and inclusive communication.

In this regard, the use of scenario-based cases, simulations, and training modules is promising. They allow pre-service teachers to analyze real or near-real pedagogical situations, anticipate learners' emotional reactions, select supportive communicative actions, practice self-regulation techniques, and receive feedback. Cases that combine inclusive interaction and digital instability play a special role. For example, a situation involving the sudden loss of video connection while working with a learner with a hearing impairment allows assessment not only of the pre-service teacher's technical response but also of their empathy, constructiveness, ability to explain further actions, and capacity to control their own emotional state.

The analysis of scholarly sources also provides grounds for clarifying the diagnostic parameters of pre-service STEM teachers' emotional intelligence in a digitally unstable, inclusive environment. These parameters may include emotional perception, regulation of one's own emotions, empathy in inclusive communication, and inclusive communicative flexibility. Emotional perception is manifested in the ability to recognize a learner's emotional state from incomplete digital signals. Regulation of one's own emotions is related to stress resilience and the ability to restore professional balance during a technical failure. Empathy in inclusive communication involves supportive verbal and nonverbal actions, avoiding stigmatizing statements, and considering special educational needs. Inclusive communicative flexibility is manifested in the readiness to change the mode of explanation, the interaction channel, or the form of support depending on the situation.

Previous studies convincingly demonstrate the significance of teachers' emotional intelligence, digital competence, and inclusive readiness. However, the issue of their simultaneous manifestation in digitally unstable situations of STEM education remains insufficiently explored. Most often, emotional intelligence is analyzed in a general pedagogical or psychological dimension; digital competence in a technological or methodological dimension; and inclusion in a normative, organizational, or didactic dimension. Less attention is paid to how a pre-service teacher behaves when these dimensions intersect in a single pedagogical situation. It is precisely such situations that demonstrate that pre-service STEM teacher professional training should include the purposeful development of emotional self-regulation, empathic communication, digital flexibility, and the ability to adapt pedagogical action quickly.

Thus, the analysis of current research enables several generalizations. First, emotional intelligence is an important component of a pre-service teacher's professional readiness because it influences motivation, engagement, interaction quality, and psychological safety in the educational environment. Second, in inclusive education, emotional intelligence is especially important because it helps teachers notice learners' individual reactions, support their participation, and prevent exclusion. Third, the digital environment creates both new opportunities and new risks for inclusive pedagogical interaction, especially under conditions of technical or organizational instability. Fourth, the preparation of pre-service STEM teachers should take into account not only subject-specific and digital components, but also emotional-communicative readiness for action in complex pedagogical situations.

This research gap underscores the study's relevance, in which the development of emotional intelligence in pre-service STEM teachers is considered a condition for inclusive pedagogical interaction in a digitally unstable educational environment. This approach allows combining theoretical analysis of contemporary research with the results of a pilot empirical evaluation of a training program aimed at developing emotion recognition, self-regulation, empathy, and the constructiveness of pedagogical action.

Given the theoretical analysis of the problem and the study's empirical focus, the following research questions were formulated.

Research Question 1. What theoretical grounds make it possible to consider the emotional intelligence of a pre-service STEM teacher as a condition for inclusive pedagogical interaction in a digitally unstable educational environment?

This question aims to clarify the relationships among emotional intelligence, inclusive readiness, digital competence, and the professional training of pre-service STEM teachers. Its formulation allows the study to go beyond empirical measurement alone and consider the results within the broader logic of contemporary teacher education.

Research Question 2. What are the dynamics of pre-service STEM teachers' ability to recognize emotions in a digital environment after participation in a training program aimed at developing emotional intelligence?

This question concerns the cognitive-perceptual component of emotional intelligence. It refers to the pre-service teacher's ability to identify another person's emotional state from limited digital signals. For inclusive interaction, this component is important because, in a digital environment, the teacher often lacks full access to the learner's nonverbal behavior.

Research Question 3. How do expert evaluations of the constructiveness of actions, empathy, and stress management of pre-service STEM teachers in a scenario-based case of inclusive digital interaction change after the formative intervention?

This question focuses on the behavioral-communicative dimension of emotional intelligence. It makes it possible to determine not only whether a pre-service teacher recognizes the learner's emotional state, but also how they propose to act in a pedagogically complex situation: whether they maintain self-regulation, show empathy, and select a constructive sequence of actions.

Taken together, these questions provide the logic of the study: from the theoretical substantiation of the problem to the analysis of changes in two interrelated dimensions of emotional intelligence: the ability to recognize emotions and the ability to act constructively in an inclusive situation of digital instability.

Research Methods

The study aimed to theoretically substantiate and empirically examine the potential for developing selected components of pre-service STEM teachers' emotional intelligence as a condition for inclusive pedagogical interaction in a digitally unstable educational environment. Given the complexity of the phenomenon under study, a combination of theoretical, empirical, and statistical methods was used.

The theoretical stage involved analyzing, systematizing, comparing, and generalizing scholarly sources on teachers' emotional intelligence, emotional competence in inclusive education, teachers' digital competence, digital inclusion, professional resilience, and the preparation of pre-service STEM teachers. This analysis enabled the study to determine its conceptual coordinates and clarify which components of emotional intelligence are most significant for pedagogical action under conditions of digital instability. Particular attention was paid to studies that connect emotional intelligence with the quality of pedagogical interaction, learners' motivation, teachers' professional well-being, inclusive readiness, and the digital transformation of the educational environment.

Based on the theoretical analysis, four diagnostically significant components of pre-service STEM teachers' emotional intelligence in a digitally unstable, inclusive environment were identified: emotional perception, regulation of one's own emotions, empathy in inclusive communication, and inclusive communicative flexibility. Emotional perception was understood as the ability to recognize learners' emotional states from limited or fragmented digital signals. Regulation of one's own emotions was defined as the pre-service teacher's ability to maintain professional balance under conditions of technical failure, uncertainty, or communicative difficulty. Empathy in inclusive communication was interpreted as readiness to notice the learner's needs, select supportive statements, and avoid stigmatizing reactions. Inclusive communicative flexibility was defined as the ability to change the channel, pace, form, or mode of pedagogical interaction in response to the situation.

The empirical part had the character of a pilot study with a "pre-test - formative intervention - post-test" design. This design was chosen because it was necessary to preliminarily examine the appropriateness and potential effectiveness of the training program aimed at developing the emotional intelligence of pre-service STEM teachers. The pilot nature of the study means that its results are treated as a basis for initial conclusions and further expansion of the research design, rather than as definitive proof of the effectiveness of the proposed approach.

The participants were 36 third- and fourth-year students receiving professional training in specialties related to future pedagogical activity in physics, mathematics, and computer science. This group was selected because pre-service STEM teachers must be ready to work with subject content of high cognitive complexity, digital tools, visualizations, simulations, and online platforms while also ensuring inclusive pedagogical interaction. Participation in the study involved completing diagnostic tasks before and after the formative intervention.

Two main instruments were used for empirical measurement. The first instrument was the test "Recognition of Emotions in a Digital Environment." Its purpose was to identify pre-service STEM teachers' ability to recognize emotional states from short digital stimuli. The main indicator was the percentage of correct responses to 30 video fragments. This format was chosen because, in real digital interaction, the teacher often perceives the learner's emotional state through incomplete signals: a short video image, a fragment of facial expression, a pause in response, a change in tone, a chat reaction, or a nonverbal signal in a video conference.

The second instrument consisted of scenario-based cases designed to evaluate pre-service teachers' actions in an inclusive digital context. The study used a case that modeled the sudden loss of video connection during interaction with a learner with a hearing impairment. This situation was chosen deliberately because it combines technical instability, an inclusive need, and emotional tension. Participants had to describe their own actions, explain how they would support the learner, and indicate how they would manage their own emotional state. Responses were evaluated by experts on three parameters: the constructiveness of actions, empathy, and stress management. Each of these parameters reflected a separate aspect of the behavioral-communicative manifestation of emotional intelligence.

The constructiveness of actions was defined by the logic, consistency, and pedagogical appropriateness of the proposed response. A high score on this parameter meant that the participant not only identified the technical failure, but also proposed a clear algorithm of actions: establish an alternative communication channel, briefly inform the learner about the next steps, ensure access to the lesson content, check understanding of the instruction, and preserve the learner's participation in the work. Empathy was evaluated through the presence of supportive wording, attention to the learner's emotional state, and avoidance of evaluative or stigmatizing statements. Stress management reflected the participant's ability to describe methods of self-regulation: maintaining calm, taking a short pause, prioritizing actions, controlling speech pace, and using a backup plan.

The formative intervention was implemented as the training program "Emotional Intelligence for Inclusive STEM." Its content aimed to develop the components of emotional intelligence most significant for inclusive pedagogical interaction in a digital environment. The program included five content modules: diagnosis and analysis of one's own emotional reactions; recognition of learners with special educational needs' emotions from limited signals; self-regulation techniques during technical failures; empathic communication in asynchronous mode; and integrative training in conducting an inclusive STEM lesson under conditions of digital instability. The total scope of training work was one credit, of which 10 hours were allocated to in-class interaction.

The first module of the training program focused on developing emotional self-awareness. Students analyzed typical emotional reactions that may arise during pedagogical practice, including anxiety, irritation, confusion, fear of losing control of the lesson, and tension caused by technical failures. Special attention was paid to the fact that the pre-service teacher must learn to recognize not only learners' emotions, but also their own reactions, since these reactions can influence the quality of pedagogical decision-making.

The second module focused on recognizing learners' emotions from limited digital signals. Participants worked with short video fragments, descriptions of online situations, chat reactions, and incomplete nonverbal manifestations. The task of this module was to develop attentiveness to minimal signs of emotional state and to teach future educators not to make hasty conclusions when a digital signal is fragmented or ambiguous.

The third module concerned self-regulation during digital failures. Within this module, short stabilization techniques were considered, including breathing control, pausing before responding, focusing on the first necessary action, and using a prepared backup scenario. This content was important because, in a rapidly changing digital environment, the teacher often has to act quickly but not impulsively. The teacher’s emotional state affects the group's behavior, especially among learners who need additional support.

The fourth module focused on empathic communication in asynchronous mode. Participants analyzed how learner support changes when interaction occurs not through live communication but through chat, email, an LMS, or another digital channel. Separate attention was given to wording that helps preserve a sense of inclusion: brief messages about next steps, checking the accessibility of material, clarifying needs, and providing a neutral explanation of the technical problem without shifting responsibility to the learner.

The fifth module had an integrative character. Participants modeled the conduct of an inclusive STEM lesson under conditions of digital instability. They had to respond to a change in the communication channel, loss of video connection, delayed response, or the inability to use a planned digital resource. After completing the tasks, a reflection was conducted: what emotional reactions arose, which decisions were constructive, which actions could increase tension, which statements were supportive, and which should be replaced.

The study procedure included three consecutive stages. At the first stage, pre-testing was conducted, during which participants completed the test “Recognition of Emotions in a Digital Environment” and a scenario-based case. At the second stage, the training program was implemented. At the third stage, post-testing was conducted using the same types of diagnostic tasks. This procedure enabled comparison of results before and after the formative intervention along two dimensions: recognition of emotions in a digital environment and the quality of pedagogical action in an inclusive context of digital instability.

Descriptive and comparative statistics were used to process the empirical data. At the first stage, means, medians, standard deviations, minimum and maximum values, and indicator dynamics were calculated. Descriptive statistics enabled the identification of the general trend of changes after the training program and the determination of the group's variability in results.

At the second stage, the data distribution was checked for normality. The Shapiro-Wilk test was appropriate for this purpose because the sample was relatively small. If the distribution of indicators met the assumption of normality, a paired-samples Student's t-test was used to compare pre-test and post-test results. If the distribution did not meet the normality assumption, the nonparametric Wilcoxon signed-rank test for dependent samples was appropriate. This statistical analysis logic corresponds to the study design, in which the same participants were measured before and after the formative intervention.

In addition to testing for statistical significance of changes, effect size estimates were provided. For indicators analyzed using the paired-samples t-test, Cohen's d for dependent samples was appropriate. For nonparametric analysis, the corresponding effect size r could be used. Effect size estimation is important because statistical significance does not always fully reflect the practical weight of changes, especially in pilot studies with small samples. Effect size enables us to determine how substantial the changes in content were, not only according to a formal statistical criterion.

Expert evaluation was especially important for the scenario-based case. Its use was determined by the fact that case responses cannot be fully evaluated according to the principle of "correct/incorrect." They require qualitative interpretation of the logic of actions, the mode of communication, the presence of empathetic wording, and the ability to control one's own emotional state. To increase the reliability of this evaluation, clear parameters were used: constructiveness of actions, empathy, and stress management. Each parameter was evaluated separately, and a generalized indicator was then formed. This made it possible to combine the qualitative content of responses with quantitative analysis of dynamics.

The ethical aspects of the study included voluntary participation, informing students about the purpose of the work, using generalized results, and preventing personalized evaluation. Since the study concerned emotional reactions and professional behavior in complex pedagogical situations, it was important to avoid a control or assessment format that would assess participants' personal qualities. Diagnostic tasks were considered an instrument for research analysis and professional self-development, not a basis for academic student ranking.

The study has several limitations that should be considered when interpreting the results. First, the sample was small, which is consistent with the pilot nature of the work but limits the possibility of broad generalization of the findings. Second, the "pre-test - formative intervention - post-test" design without a full control group does not allow for full exclusion of external factors. Third, some indicators were based on expert evaluation, which, despite the use of criteria, may contain an element of subjectivity. Fourth, the study recorded short-term dynamics after the training program and does not answer the question of long-term retention of the developed skills.

At the same time, the pilot format enabled examination of the methodological suitability of the diagnostic instruments and the training program. The obtained data can be used to further expand the study: increasing the sample, including a control group, using several types of inclusive cases, comparing different training intervention formats, and conducting a delayed post-test. Such development of the research design will enable more precise assessment of the extent to which the development of pre-service STEM teachers' emotional intelligence affects their readiness for inclusive pedagogical interaction in a digitally unstable educational environment.

Research Results

The empirical part of the study aimed to identify the dynamics of selected components of pre-service STEM teachers' emotional intelligence following their participation in the training program "Emotional Intelligence for Inclusive STEM." The main attention was focused on two dimensions. The first dimension concerned the ability to recognize emotional states in a digital environment. The second dimension reflected pre-service teachers' readiness to act in a situation of inclusive digital interaction complicated by a technical failure.

The study involved 36 students receiving professional training as pre-service teachers of physics, mathematics, and computer science. The study was a pilot study and used the "pre-test - formative intervention - post-test" design. This logic enabled comparisons of results before and after the training program and the determination of whether changes occurred in indicators related to emotional perception, empathy, the constructiveness of pedagogical action, and stress management.

Dynamics of the Results of the Test "Recognition of Emotions in a Digital Environment"

The first diagnostic instrument was designed to assess pre-service STEM teachers' ability to recognize emotional states from short digital stimuli. The main indicator was the percentage of correct responses to 30 video fragments. This indicator reflects the cognitive-perceptual component of emotional intelligence, namely the ability to notice and interpret emotional signals under conditions of fragmented, limited, or mediated information.

At the pre-test stage, the mean correct emotion recognition rate was 65.08%. The median value was 66.00%, and the standard deviation was 8.97. The minimum result was 49%, and the maximum was 79%. These data indicate a moderate initial level of pre-service teachers' ability to recognize emotions in a digital environment. At the same time, the noticeable variability of results shows that the participants had different initial experiences and different sensitivities to emotional signals.

After participation in the training program, the mean increased to 74.11%, the median to 74.00%, and the standard deviation decreased to 5.47%. The minimum post-test score was 65%, and the maximum was 83%. The decrease in standard deviation after training indicates not only an overall improvement in results, but also a certain leveling of the group. In other words, after the formative intervention, the participants' results became less dispersed, and the lower boundary of test performance increased (Table 1).

Table 1

Descriptive Statistics for the Results of the Test "Recognition of Emotions in a Digital Environment"

Indicator	Pre-test	Post-test	Individual changes
Number of participants	36	36	36
Mean	65.08	74.11	+9.03
Median	66.00	74.00	+7.50
Standard deviation	8.97	5.47	10.57
Minimum value	49	65	-11
Maximum value	79	83	+31

Note. The "Individual changes" column presents descriptive indicators of individual differences between the post-test and pre-test.

Source: Authors' own work.

The mean gain was 9.03 percentage points, and the median gain was 7.50 percentage points. Individual changes were heterogeneous: 28 out of 36 participants showed an increase in results, while 8 participants showed a decrease. There were no cases of complete absence of change. Thus, the overall trend was positive, although not all participants responded equally to the training intervention.

The Shapiro-Wilk test of the distribution of differences between the pre-test and post-test did not reveal a statistically significant deviation from normal distribution, $W = 0.969$; $p = 0.399$. This provided grounds for using the paired-samples Student's t-test to compare dependent samples. The analysis showed a statistically significant increase in emotion recognition after the training program: $t(35) = 5.123$; $p < 0.001$. The effect size according to Cohen's dz was 0.85, which can be interpreted as a large effect.

These results indicate that, after participation in the training program, a noticeable improvement was recorded in pre-service STEM teachers' ability to recognize emotional states in a digital environment. The increase in the minimum result from 49% to 65% is especially significant. This means that, after the formative intervention, even participants with lower initial indicators demonstrated a more acceptable level of test performance. For inclusive digital interaction, this has practical significance, since the teacher must be able to notice the learner's emotional difficulties even when the communication channel is limited.

At the same time, the results should not be interpreted as absolute confirmation of fully developed emotional intelligence. The test assessed only one component: the ability to recognize emotional states. Emotional intelligence in pedagogical activity has a broader structure and includes not only emotion recognition but also self-regulation, empathetic responses, communicative flexibility, and the ability to make pedagogically appropriate decisions. This is why a scenario-based case was chosen as the second instrument of the study.

Results of Completing the Scenario-Based Case of Inclusive Digital Interaction

The second diagnostic instrument was designed to assess how pre-service STEM teachers behave in a pedagogical situation that simultaneously involves an inclusive need, a digital failure, and emotional tension. Participants were presented with a case in which the video connection suddenly drops during interaction with a learner with hearing impairment. This situation is indicative because the loss of the video channel may deprive the learner of an important way to receive information, including visual signals, captions, and the opportunity to see the teacher's articulation and gestures.

Participants' responses were evaluated by experts on three parameters: the constructiveness of actions, empathy, and stress management. The generalized case score reflected not only the correctness of a separate action, but also the overall quality of pedagogical response. High results presupposed that the pre-service teacher proposed a consistent action plan, maintained attention to the learner's emotional state, used supportive wording, selected an alternative communication channel, and demonstrated the ability to control their own tension.

At the pre-test stage, the mean for the scenario-based case was 5.47, the median was 5.00, and the standard deviation was

2.96. The minimum value was 0 points, and the maximum was 10 points. These results show that, at the initial stage, a considerable number of participants had difficulty constructing a holistic pedagogical response to an inclusive digital situation. Some responses were likely focused mainly on the technical aspects of the failure, whereas the learner's emotional support and the teacher's self-regulation were less clearly represented.

After the training program, the mean increased to 10.67 points, the median to 10.00 points, and the standard deviation to 2.83. The minimum result after the training was 5 points, and the maximum was 15 points. The increase in the minimum value from 0 to 5 points is especially indicative, as it shows a decrease in weakly structured or pedagogically incomplete responses. After the training, all participants demonstrated at least a basic ability to propose a sequence of actions in a complex situation (Table 2).

Table 2
Descriptive Statistics for the Results of Completing the Scenario-Based Case

Indicator	Pre-test	Post-test	Individual changes
Number of participants	36	36	36
Mean	5.47	10.67	+5.19
Median	5.00	10.00	+5.00
Standard deviation	2.96	2.83	4.03
Minimum value	0	5	-3
Maximum value	10	15	+13

Note. The "Individual changes" column presents descriptive indicators of individual differences between the post-test and pre-test.

Source: Authors' own work.

The mean gain was 5.19 points, and the median was 5 points. Individual changes were clearly positive: 31 of 36 participants improved their results, 1 remained at the same level, and 4 decreased. This distribution indicates that the positive dynamics were more pronounced for the behavioral-communicative component than for test-based emotion recognition.

The Shapiro-Wilk test of the distribution of differences showed no statistically significant deviation from normal distribution, $W = 0.982$; $p = 0.819$. Therefore, the paired-samples Student's t-test was used to compare pre-test and post-test results. The results showed a statistically significant increase in expert evaluations after the training program: $t(35) = 7.739$; $p < 0.001$. The effect size according to Cohen's dz was 1.29, which corresponds to a very large effect.

The obtained data provide grounds for stating that the most pronounced changes occurred in pre-service STEM teachers' ability to describe pedagogically appropriate actions in an inclusive digital context. If, at the pre-test stage, participants' responses could be fragmentary, technically oriented, or insufficiently empathic, after the training, they more often included several interconnected components: rapid establishment of an alternative communication channel, a brief explanation of the situation, support for the learner, checking the accessibility of the material, maintaining calm, and using a backup scenario.

This result is methodologically significant because the scenario-based case was closer to real professional action than the test task. In the test, the participant had to identify an emotional state; in this case, they had to propose a pedagogical decision. Therefore, the increase in the case indicator may suggest that the training program contributed not only to improved emotion recognition but also to a more holistic understanding of inclusive interaction under conditions of digital instability.

Comparison of Dynamics Across the Two Indicators

The comparison of results from the two diagnostic instruments shows that positive dynamics were observed in both dimensions, though their magnitudes differed. In the test "Recognition of Emotions in a Digital Environment," the mean gain was 9.03 percentage points, and the effect size was 0.85. In the scenario-based case, the mean gain was 5.19 points, and the effect size was 1.29. Thus, greater changes were identified in the case-based indicator (Table 3).

Table 3
Summary of Result Dynamics Across the Two Instruments

Instrument	Mean before	Mean after	Mean gain	Statistical criterion	Effect size
Emotion recognition test	65.08	74.11	+9.03	$t(35) = 5.123$; $p < 0.001$	$dz = 0.85$
Scenario-based case	5.47	10.67	+5.19	$t(35) = 7.739$; $p < 0.001$	$dz = 1.29$

Source: Authors' own work.

This difference may have several explanations. First, the training program was largely practice-oriented. It included analyzing situations, rehearsing responses, discussing support strategies, and reflecting on one's own emotional state. Therefore, its effect may have been more pronounced in case-based responses, where participants had to describe a sequence of actions rather than simply complete an emotion recognition task.

Second, recognizing emotions from digital stimuli requires more extensive training. A short training intervention may improve attentiveness to emotional signals, but accuracy in recognizing facial expressions, micro-expressions, or emotional states from short fragments develops gradually. By contrast, case-based responses could improve more quickly because participants received clearer algorithms of pedagogical action, worked through examples of supportive communication, and learned to structure their own responses.

Third, the scenario-based case allowed participants to apply not only emotional perception, but also pedagogical thinking. Even if a pre-service teacher does not always accurately identify a learner's emotional state, they can propose a supportive action if they understand the logic of inclusive interaction. Therefore, the case-based indicator reflected a broader set of abilities: empathic communication, professional self-regulation, digital flexibility, and the ability to act under conditions of uncertainty.

At the same time, the two results complement each other. The increase in test scores indicates improvement in emotional perception, whereas the increase in case scores indicates strengthened readiness for pedagogical action. For a pre-service STEM teacher, both dimensions are important. In a digitally unstable, inclusive environment, the teacher must first notice the learner's emotional state and then respond quickly and appropriately. If the first component is weak, the teacher may not notice the need for support. If the second component is insufficient, even accurate emotion recognition will not turn into effective pedagogical action.

Qualitative Interpretation of Changes in Participants' Responses

The quantitative dynamics of the results are complemented by a qualitative interpretation of changes in participants' responses to the scenario-based case. At the pre-test stage, a considerable proportion of responses were mainly technical in nature. Participants often focused on the need to "reconnect," "write in the chat," "restart the platform," or "repeat the explanation." These actions are important; however, they do not always take into account the inclusive specificity of the situation. For a learner with a hearing impairment, a technical failure means not just an interruption of the lesson but the loss of an accessible communication channel.

After the training program, responses were more often comprehensive. Participants described not only the technical restoration of the connection, but also pedagogical support for the learner: informing them about the situation through a short written message, switching to a backup channel, checking whether the learner could see the instruction, providing the material in text format, offering a short pause, repeating the content after the connection was restored, and avoiding irritation or haste. In such responses, inclusive communicative flexibility became more clearly visible.

Separate changes concerned empathy. At the initial stage, supportive wording appeared less often or remained general. After the training, participants more frequently used statements that acknowledged the learner's possible discomfort while preserving their agency: "I will inform the learner that the situation is under control," "I will explain that the problem is technical and not related to their actions," "I will offer an alternative way to continue working," and "I will check which channel is currently available for them." Such wording matters because support in inclusive interaction should not be paternalistic or stigmatizing.

Changes were also observed in the description of self-regulation. At the pre-test stage, participants did not always explain exactly how they would control their emotional state. After the training, responses more often included references to a short pause, control of speech pace, prioritization of actions, use of a backup plan, and maintaining a calm tone. This is important because, in a situation of digital failure, the teacher's pedagogical response can either stabilize the group or increase tension. For a learner with special educational needs, the teacher's emotional stability is one of the factors of safe participation in the lesson.

Thus, the qualitative interpretation confirms the quantitative results. After the training program, participants' responses became more structured, empathic, and professionally oriented. They more often combined technical action, inclusive support, and the pre-service teacher's self-regulation. This combination is important for preparing a pre-service STEM teacher to work in a digitally unstable educational environment.

Summary of Results

The pilot study results showed positive dynamics for both diagnostic instruments. After participating in the training program, pre-service STEM teachers demonstrated greater ability to recognize emotions in a digital environment and described their own actions more effectively in inclusive digital interactions. Statistical analysis confirmed the significance of the changes for both the test indicator and the scenario-based case results.

The most pronounced changes were recorded in the completion of the scenario-based case. This provides grounds for assuming that the positive dynamics after the training program were especially pronounced in the practical, behavioral-communicative dimension of emotional intelligence. Participants not only became more aware of the importance of emotional support, but also more often proposed specific actions that could be used in a real, inclusive digital situation. They demonstrated greater attention to the learner's needs, the ability to switch communication channels, and an understanding of the need for their own self-regulation.

The improvement in the test results for "Recognition of Emotions in a Digital Environment" indicates positive dynamics in emotional perception. Participants became more accurate in identifying emotional states from digital stimuli, which is important for online and blended learning. However, this indicator requires further development, since emotion recognition in a digital environment remains a complex task. It depends not only on the participant's training but also on the quality of the digital signal, the duration of observation, the cultural characteristics of emotional expression, and individual characteristics of learners.

Overall, the obtained results provide grounds for considering the training program "Emotional Intelligence for Inclusive STEM" as a promising means of developing selected components of pre-service STEM teachers' emotional intelligence. The combination of work with emotional signals, inclusive cases, self-regulation, and digital failures proved especially productive. Such integration corresponds to the real conditions of a pre-service teacher's professional activity, in which subject content, the digital environment, learners' emotional states, and inclusive support do not exist separately.

At the same time, the results should be interpreted with regard to the study's pilot nature. The small sample, the short duration of the formative intervention, the absence of a full control group, and the use of expert evaluation limit the possibility of broad generalization. Nevertheless, the obtained data are sufficient for a preliminary conclusion about the appropriateness of further developing this direction. The next stages of the study should include expanding the sample, comparing results with a control group, using several types of inclusive situations, and conducting delayed measurement to verify the stability of the developed skills.

Discussion

The obtained results provide grounds for considering the development of emotional intelligence in pre-service STEM teachers as a pedagogically significant area of their professional preparation for inclusive interaction in a digitally unstable educational environment. After participation in the training program "Emotional Intelligence for Inclusive STEM," statistically significant increases were observed in two indicators: the ability to recognize emotions in a digital environment and the quality of responses to a scenario-based case in which a digital failure complicated interaction with a learner with a hearing impairment. This indicates that pre-service STEM teachers' emotional intelligence can be developed not only through general psychological exercises, but also through professionally oriented tasks related to digital educational situations, inclusive support, empathic communication, and self-regulation.

The positive dynamics in the emotion recognition test are consistent with studies linking teachers' emotional intelligence to the quality of pedagogical interaction, learners' motivation, and the teacher's ability to create a supportive educational environment. Rahman et al. (2024) show that teachers' emotional intelligence is associated with learners' motivation for academic learning, while its components, including self-awareness, self-regulation, motivation, empathy, and social skills, directly influence the nature of educational interaction. In our study, this thesis is specified in relation to pre-service STEM teachers: the ability to recognize emotional states in a digital environment is a prerequisite for timely pedagogical support when a learner may feel confusion, anxiety, or a sense of exclusion due to a technical failure.

The broader significance of the obtained results can be explained through the conclusions of Bardach et al. (2021), who, in an integrative review, show that teachers' psychological characteristics are related to teaching effectiveness, professional well-being, retention in the profession, and the quality of interpersonal relationships. In our study, it is important that emotional intelligence not be considered an isolated individual trait. It belongs to the system of teachers' professional functioning. A pre-service STEM teacher must work with complex subject content, digital tools, diverse learning paces, inclusive needs, and unpredictable technical issues. Under such conditions, emotional self-regulation and the ability to notice another person's state become not auxiliary, but professionally necessary characteristics.

The most pronounced changes in our study were recorded for the scenario-based case. This means that the positive dynamics were especially visible in the behavioral-communicative dimension of emotional intelligence. This result is consistent with the position of Calandri et al. (2025), who, in a systematic review, emphasize that teachers' emotional competence in inclusive education includes emotional intelligence, emotional awareness, empathy, and emotion regulation. These components influence learner engagement, motivation, emotional self-regulation, and educational outcomes. In our case, it was the scenario-based case that made it possible to see how pre-service teachers integrate these components into pedagogical action: whether they are able not only to respond technically to a failure, but also to support the learner, preserve their participation in the lesson, change the communication channel, and at the same time stabilize their own emotional state.

The results of the study also resonate with the work of Ayeni et al. (2024), which considers emotional intelligence and counseling techniques as means of strengthening STEM education. The authors emphasize that STEM education requires not only cognitive preparation but also the development of resilience, focus, interpersonal skills, and motivation. Our study extends this position toward inclusive digital interaction. In STEM learning, emotional difficulties may arise from content complexity, errors, uncertainty, and the pace of work, and, in the digital environment, they may be intensified by unstable access or the loss of a communication channel. Therefore, the preparation of a pre-service STEM teacher should include not only methods for explaining complex material, but also the ability to support a learner in an emotionally tense situation.

It is important that positive dynamics were found not only in cognitive emotion recognition, but also in the ability to construct a response to an inclusive case. This corresponds to works that consider emotional intelligence through communicative practices. Hrona et al. (2024) outline the potential for developing emotional intelligence through cognitive, native-language teaching, emphasizing the roles of speech, semantic interpretation, emotionally charged situations, and awareness of internal states. Although their study is not directly related to STEM teacher preparation, it is important for explaining the obtained results: emotional intelligence is formed not only through knowledge about emotions, but also through verbal processing of situations in which one needs to understand another person's state and choose an appropriate way to respond.

A similar logic can be traced in the work of Semenog et al. (2024a), where communicative tasks are considered as a means of developing learners' emotional intelligence. In our study, this idea is confirmed through the results of case-based assessment. After the training, participants more often proposed not only a technical action, such as "restore the connection" or "move to the chat," but also supportive communicative steps: briefly explaining the situation, reassuring the learner, checking which communication channel is available to them, sending the material in text format, and repeating key instructions after the connection is restored. Thus, the increase in case results can be explained by the fact that pre-service teachers began to see the pedagogical situation more clearly as communicative rather than only technical.

This conclusion is also consistent with the study by Semenog et al. (2024b), which considers the development of emotional intelligence within the system "teacher - learner - language training" based on a communicative approach. In our problem area, it is important that emotional intelligence is manifested not only in an individual's capacity but also in the system of interaction. In a digitally unstable environment, this systemic character becomes especially visible. If the video connection disappears, chat is disrupted, or the platform changes, the teacher has to restore not only the technical connection, but also pedagogical interaction. The teacher must ensure that the learner feels the situation is under control, that their participation is preserved, and that the next steps are clear.

In this case, the culture of professional communication becomes one of the practical manifestations of emotional intelligence. Kharchenko and Semenikhina (2024) analyze the links between professional communication culture and emotional intelligence, which provides an important framework for interpreting our results. In responses to the case after the training, participants more often demonstrated professionally appropriate communication: they did not shift responsibility for the failure onto the learner, avoided harsh or evaluative wording, offered support options, and tried to maintain a calm tone. This indicates that the development of emotional intelligence in pre-service STEM teachers should be linked to the formation of their professional speech, especially in situations where the teacher’s words can reduce or, conversely, increase tension.

The obtained results should also be considered in relation to the digital transformation of education. Gómez-Pablos et al. (2022) show that teachers’ digital competencies in higher education remain unevenly developed, with especially problematic areas including the practical use of digital tools, assessment, and personalized support. Our study specifies this problem: the digital competence of a pre-service STEM teacher should include not only the ability to use platforms or digital resources, but also the capacity to maintain pedagogical interaction when these resources function unstably. Technical preparedness is necessary but insufficient. If the teacher is unable to stabilize the situation emotionally and communicatively, digital instability may lead to the loss of the learner’s participation.

This idea is strengthened by the findings of Arif et al. (2025), who emphasize that teachers’ competence in the digital age cannot be reduced to proficiency in individual programs. It involves creating an educational environment that supports collaboration, creativity, critical thinking, and responsible participation. In our study, responsible participation acquires an inclusive meaning. The teacher must ensure that a learner with special educational needs is not excluded from the lesson due to a technical issue. This requires digital flexibility, emotional sensitivity, and the ability to quickly restructure pedagogical action.

According to Amemasor et al. (2025), teachers' professional development in digital education is more effective when it has a practical, sustained, and supportive character and includes mentoring, institutional support, and work with real pedagogical situations. Our results confirm the appropriateness of a practice-oriented approach. The greatest changes were recorded not where participants only recognized emotions, but where they applied knowledge in a modeled pedagogical situation. Therefore, the preparation of pre-service STEM teachers for digitally unstable inclusive interaction should be based on training sessions, cases, micro-simulations, reflection, and analysis of their own communicative actions.

The connection between digital technologies and emotional development under crisis conditions is discussed in detail in the work of Shyshenko et al. (2024), which shows the use of digital technologies in studying mathematical analysis as a basis for developing learners' emotional intelligence under new crisis conditions. This study is particularly close to our topic because it combines mathematical preparation, digital technologies, and emotional development. Our results develop this line, but shift the emphasis from the development of learners' emotional intelligence to the preparation of a pre-service teacher for emotionally sensitive pedagogical action. In addition, in our study, the digital environment is considered not only as a resource, but also as a potentially unstable space in which the teacher must be ready for loss of access, a change in the communication channel, or disruption of the usual lesson scenario.

The digital environment can support inclusion only if the teacher uses it pedagogically. Navas-Bonilla et al. (2025) show that technologies and specialized devices can support inclusive education by ensuring accessibility, personalization, and participation of learners with diverse needs. At the same time, the results of our study show another side of this problem: if the technological channel is suddenly disrupted, the teacher must not simply restore technical functioning, but preserve the inclusive quality of interaction. Therefore, the inclusiveness of the digital environment depends not only on tools but also on the teacher's emotional and communicative readiness.

The area of AI literacy and digital ethics in the training of pre-service teachers is also significant for interpreting the results. Ayanwale et al. (2024) show that understanding artificial intelligence is related to pre-service teachers' readiness to use it, engage in ethical reflection, and solve problems. Ng et al. (2023) propose an affective-behavioral-cognitive-ethical framework of AI literacy, in which not only knowledge and skills but also motivation, confidence, collaboration, and ethical learning are important. For our study, this means that the digital preparation of a pre-service STEM teacher should include affective and ethical dimensions. The teacher must understand how digital or AI tools affect the learner's autonomy, accessibility, emotional state, and dignity.

Zhang and Zhang (2024) consider AI in teacher education as a resource for teaching support, inclusive learning, digital literacy, personalization, and strengthening interaction between the teacher and learners. Our study partly confirms this logic, but also shows that any digital support requires pedagogical sensitivity. Technology can provide adaptation tools, but it is the teacher who decides how to act in a situation of instability, how to support the learner, and how to preserve educational interaction without humiliation, haste, or formal shifting of responsibility onto a digital system.

The issue of individualizing educational interaction requires particular attention. Yurchenko et al. (2023) consider the construction of an individual educational trajectory as an important skill of a successful teacher in the digital age. In our study, this idea is specified through the inclusive case. When a learner with a hearing impairment loses video connection, the teacher should not simply continue the lesson for the group, but adapt the trajectory of participation for the specific learner: provide written instructions, offer a backup channel, check the accessibility of the material, and repeat the content after the connection is restored. Thus, digital flexibility and emotional intelligence become conditions not only for inclusion, but also for genuine individualization of learning.

The results of the study can also be compared with works on crisis and emergency conditions of digital education. Beardsley et al. (2021) show that the emergency transition to distance learning affected teachers’ skills and motivation to use digital technologies, but also revealed the need for sustained support, preparation, and reconsideration of the teacher’s professional role. Mhlongo et al. (2023) emphasize that the use of smart digital technologies in educational environments has not only advantages, but also challenges related to accessibility, unequal participation, organizational readiness, and the pedagogical quality of digital solutions. Our results confirm that digital instability is not a peripheral factor, but a pedagogically significant one. It affects learners’ participation, especially those who have specific communicative needs.

Comparing the two empirical indicators allows us to formulate one additional methodological generalization. The increase in emotion recognition test results was statistically significant and had a large effect, but even greater changes occurred in the scenario-based case. This may indicate that a short-term training program more quickly affects awareness and the structure of pedagogical action than the automated accuracy of recognizing emotional signals. Recognizing emotions from digital stimuli requires longer practice, whereas the ability to construct an appropriate algorithm of support may improve noticeably after working through cases, communicative formulas, and self-regulation techniques.

This has significance for the design of educational programs. If the goal is to develop pre-service STEM teachers’ emotional intelligence specifically as a component of professional readiness, it is insufficient to limit training to separate lectures on emotions or psychological tests. A combination of at least three types of tasks is needed. The first type includes tasks for recognizing emotional states in a digital environment. The second includes communicative exercises in which the pre-service teacher selects supportive statements, explanations, instructions, and feedback options. The third includes scenario-based cases and micro-simulations that require taking into account STEM content, an inclusive need, a digital failure, and one’s own self-regulation simultaneously. This approach is consistent with findings on communicative means of developing emotional intelligence (Hrona et al., 2024; Semenog et al., 2024a; Semenog et al., 2024b), as well as with studies of teachers' professional development in the digital age (Amemasor et al., 2025; Gómez-Pablos et al., 2022).

The obtained data enable clarification of pre-service STEM teachers' readiness for inclusive pedagogical interaction in a digitally unstable environment. Such readiness cannot be reduced only to digital competence, knowledge of inclusive principles, or mastery of STEM methodology. It includes the ability to notice the learner's emotional state, understand the impact of a technical failure on their participation, quickly switch communication channels, support a sense of safety, maintain one's own self-regulation, and select professionally appropriate wording. For this reason, emotional intelligence should be considered an integrating component between the digital, inclusive, communicative, and methodological readiness of the pre-service teacher.

The practical significance of the obtained results lies in the need to include specialized modules in pre-service STEM teachers' preparation to develop emotional self-regulation, empathic communication, digital flexibility, and pedagogical action in nonstandard inclusive situations. Such modules can be integrated into courses on STEM teaching methodology, digital educational technologies, inclusive education, pedagogical practice, or professional communication. Their content should be built not only on theoretical provisions, but also on analysis of video fragments, digital micro-situations, cases, backup lesson scenarios, and reflection on one's own emotional reactions.

At the same time, the interpretation of the results should be cautious. The study was a pilot, the sample was small, and the "pre-test - formative intervention - post-test" design does not allow for full exclusion of external factors. In addition, the scenario-based case reflected only one type of inclusive digital situation related to hearing impairment and video connection loss. In the future, it would be advisable to expand the set of cases to include situations related to different special educational needs, different types of digital instability, different STEM disciplines, and different educational interaction formats. It is also advisable to include a control group, delayed measurement, and analysis of the stability of the developed skills.

Despite these limitations, the results have sufficient analytical weight for a preliminary conclusion about the promise of the chosen approach. They are consistent with contemporary studies of teachers' emotional intelligence, inclusive education, digital competence, AI literacy, professional communication, and STEM teacher preparation (Ayanwale et al., 2024; Bardach et al., 2021; Calandri et al., 2025; Gómez-Pablos et al., 2022; Hrona et al., 2024; Navas-Bonilla et al., 2025; Ng et al., 2023; Shyshenko et al., 2024; Zhang & Zhang, 2024). At the same time, they specify this problem area by situating it within the field of digitally unstable inclusive interaction among pre-service STEM teachers.

Thus, the study results confirm the appropriateness of considering emotional intelligence as a condition for inclusive pedagogical interaction in a digitally unstable educational environment. For a pre-service STEM teacher, this condition is not auxiliary, but professionally significant. It determines the teacher's ability not only to teach complex content using digital technologies, but also to support learners' participation, respond to unpredictable situations, maintain emotional balance, and ensure such pedagogical interaction in which digital instability does not lead to educational exclusion.

Conclusions

The chapter substantiated the appropriateness of considering pre-service STEM teachers' emotional intelligence as a condition for inclusive pedagogical interaction in a digitally unstable educational environment. The theoretical analysis showed that contemporary STEM teacher preparation cannot be limited to subject-specific, methodological, and digital components. It should also include emotional-communicative readiness to work with diverse educational needs, complex learning situations, unpredictable technical failures, and learners' emotional responses. In this logic, emotional intelligence is not a general personal trait but a professionally significant resource for pedagogical action.

It was established that, for a pre-service STEM teacher, components of emotional intelligence directly related to inclusive digital interaction are particularly important: emotional perception, self-regulation, empathy, and inclusive communicative flexibility. Emotional perception enables the detection of a learner’s state from incomplete digital signals. Self-regulation enables the teacher to maintain professional balance in the face of technical failure. Empathy helps take into account the learner’s experiences and needs without stigmatization or formal response. Inclusive communicative flexibility is manifested in the ability to change the channel, pace, form, or mode of pedagogical support according to a specific situation.

The analysis of current research showed that teachers’ emotional intelligence is related to learners’ motivation, the quality of pedagogical interaction, teachers’ professional well-being, the culture of professional communication, and inclusive support. At the same time, scholarly literature has not sufficiently addressed situations in which emotional competence, digital competence, inclusive readiness, and STEM methodology intersect in a single pedagogical action. Such situations arise in a digitally unstable environment, when a technical failure affects not only the organization of a lesson but also the accessibility of participation, the sense of safety, and the learner's emotional state.

The empirical part of the study was designed as a pilot evaluation of the training program “Emotional Intelligence for Inclusive STEM.” Its content combined work with emotional self-awareness, recognition of emotions through digital signals, self-regulation techniques during technical failures, empathic asynchronous communication, and modeling an inclusive STEM lesson under conditions of digital instability. This content was methodologically justified because it addressed the real challenges of pre-service teachers’ professional activity: working simultaneously with complex subject content, digital tools, diverse educational needs, and participants' emotional states in the educational process.

The results of the test “Recognition of Emotions in a Digital Environment” showed positive dynamics in the cognitive-perceptual component of emotional intelligence. The mean indicator of correct emotion recognition increased from 65.08% at the pre-test stage to 74.11% at the post-test stage. The difference was statistically significant, and the effect size indicated practically noticeable dynamics. This provides grounds for concluding that purposeful work with digital emotional signals may improve pre-service STEM teachers' ability to recognize emotional states in mediated communication.

Even more pronounced dynamics were identified in the results of the inclusive digital interaction scenario. The mean expert evaluation score increased from 5.47 to 10.67 points. This indicates that, after the training program, pre-service STEM teachers more often described pedagogically appropriate actions in a situation where a technical failure complicated interaction with a learner with a hearing impairment. Participants' responses more frequently included components such as establishing an alternative communication channel, providing written support, checking the material's accessibility, calmly explaining the situation, avoiding stigmatizing reactions, and controlling their own emotional state.

The comparison of the two diagnostic instruments showed that the positive dynamics after the training program were more pronounced in the behavioral-communicative dimension of emotional intelligence than in the accuracy of recognizing emotional signals. This can be explained by the program's practice-oriented content: participants not only became familiar with the concepts of emotional intelligence but also worked through cases, selected supportive wording, analyzed their own reactions, and modeled actions under conditions of digital instability. This result confirms the appropriateness of using scenario-based, communicative, and reflective tasks in preparing pre-service STEM teachers.

The generalization of the results provides grounds for stating that the emotional intelligence of a pre-service STEM teacher serves as an integrating function between digital, inclusive, communicative, and methodological readiness. It helps the teacher not only see a technical problem, but also understand its consequences for a specific learner. It supports the ability to act calmly, professionally, and flexibly when the usual lesson scenario is disrupted. It also helps preserve the learner's participation in the educational process, especially if the learner has special educational needs and depends on a particular communication channel.

The practical significance of the obtained results lies in the fact that pre-service STEM teacher preparation should include specialized modules aimed at developing emotional self-regulation, empathetic communication, digital flexibility, and action in non-standard inclusive situations. Such modules should be integrated into courses on STEM teaching methodology, digital educational technologies, inclusive education, pedagogical practice, and professional communication. Their content should be based not only on theoretical explanation of emotional intelligence, but also on the analysis of video fragments, digital micro-situations, cases, backup lesson scenarios, and reflection on one's own pedagogical action.

The obtained results should be interpreted with regard to the study's limitations. The pilot nature of the work, the small sample, the absence of a full control group, the short duration of the formative intervention, and the use of expert evaluation do not allow for broad generalization. In addition, the scenario-based case reflected only one type of inclusive digital situation. Therefore, the results should be considered preliminary empirical confirmation of the proposed approach's promise, rather than final proof of its effectiveness across all groups of pre-service STEM teachers.

Prospects for further research include expanding the sample, including a control group, using delayed post-testing, comparing different training intervention formats, and developing a broader set of inclusive digital cases. It would also be appropriate to examine how the developed skills manifest themselves not only in written responses, but also in real or simulated fragments of STEM lessons. A separate study is needed to examine the influence of such programs on pre-service teachers' readiness to work with different categories of learners, across different digital platforms, and in the face of different types of instability.

Thus, the results of the theoretical and empirical analyses confirm the appropriateness of including the development of emotional intelligence in the professional preparation system for pre-service STEM teachers. In a digitally unstable inclusive educational environment, the teacher must be ready not only to transmit knowledge and use technologies, but also to support learners' participation, safety, and dignity. For this reason, emotional intelligence should be considered one of the conditions of pre-service STEM teachers' professional capacity to act responsibly, flexibly, and humanely in situations where educational interaction requires not a standard algorithm, but an attentive pedagogical decision.

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EPILOGUE

Olena Semenikhina

The inclusive transformation of education is not a completed reform or a set of isolated measures. It is a continuous process of rethinking how educational systems, institutions, and teachers respond to human diversity, instability, and unequal access to opportunities. The chapters of this monograph show that inclusion becomes effective only when it is supported simultaneously by institutional responsibility, organizational partnership, pedagogical flexibility, digital accessibility, personalized support, and emotional sensitivity.

Equal access to educational resources is the starting point of this transformation. Without accessible environments, reasonable accommodation, universal design, digital inclusion, inclusive safety, and clear institutional mechanisms, the right to education remains vulnerable to formalism. Yet access alone is not enough. Learners must not only enter educational spaces but also participate meaningfully in them, feel supported, receive adapted forms of assistance, and have real opportunities to achieve educational outcomes.

Partnership interaction strengthens this process by changing the internal culture of educational institutions. Under unstable conditions, no single actor can provide educational resilience on their own. Teachers, learners, parents, administrators, support specialists, community representatives, and external partners need coordinated forms of cooperation. Partnership, therefore, is not merely a moral appeal to mutual respect. It is a practical condition for the sustainable functioning of educational institutions that must adapt to uncertainty, crisis, digital disruption, and changing social needs.

Personalized pedagogical support gives inclusion its practical form. It is through personalization that the abstract principle of equal access becomes a specific pedagogical decision: to change the explanation, adapt the task, offer another route, slow down the pace, use visual support, provide paper-based materials, or help a learner return to work after interruption. In STEM education, where learners often face cognitive, emotional, and digital barriers, personalization is especially important. It allows the teacher to preserve high expectations while making the path toward learning more accessible and humane.

Emotional intelligence completes this logic by reminding us that inclusion is not only about structures, technologies, standards, and methods. It is also about the quality of human interaction. A learner may have access to resources and adapted tasks, but still feel excluded if communication is insensitive, hurried, stigmatizing, or emotionally unsafe. For this reason, the teacher's ability to recognize emotions, regulate stress, communicate empathetically, and maintain calm during digital or organizational disruptions becomes a professional requirement for inclusive education.

The general conclusion emerging from this monograph is that inclusive education under conditions of instability requires a shift from reactive support to proactive design. Educational environments should not wait until barriers become visible. They should be designed from the beginning as flexible, accessible, participatory, digitally reliable, where possible, and emotionally safe. This concerns higher education institutions, schools, teacher education programs, digital platforms, management models, and everyday pedagogical practices.

For Ukrainian education, this task is particularly significant. The challenges caused by war, displacement, interrupted learning, digital inequality, and psychological vulnerability have made visible many barriers that previously remained hidden or underestimated. At the same time, these challenges have opened space for renewal. They have shown that resilience in education is not created by technology alone, nor by regulations alone. It is created by the combination of institutional decisions, professional cooperation, pedagogical creativity, digital flexibility, and attention to the dignity of every learner.

The monograph, therefore, affirms a central idea: inclusive transformation is not an additional direction of educational development, but one of its necessary foundations. Education that seeks to remain relevant in conditions of instability must guarantee access, build partnerships, personalize support, and preserve the human quality of pedagogical interaction. Only in this way can educational institutions become not merely places of instruction, but environments where every learner has the possibility to participate, develop, and be recognized.

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