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.

References

Amemasor, S. K., Oppong, S. O., Ghansah, B., Benuwa, B.-B., & Essel, D. D. (2025). A systematic review on the impact of teacher professional development on digital instructional integration and teaching practices. *Frontiers in Education, 10*, Article 1541031. https://doi.org/10.3389/feduc.2025.1541031

Arif, M., Abd Aziz, M. K. N., & Ma'arif, M. A. (2025). A recent study on Islamic religious education teachers' competencies in the digital age: A systematic literature review. *Journal of Education and Learning (EduLearn), 19*(2), 1194–1204. https://doi.org/10.11591/edulearn.v19i2.21311

Ayanwale, M. A., Adelana, O. P., Molefi, R. R., Adeeko, O., & Ishola, A. M. (2024). Examining artificial intelligence literacy among pre-service teachers for future classrooms. *Computers and Education Open, 6*, Article 100179. https://doi.org/10.1016/j.caeo.2024.100179

Ayeni, O. O., Chisom, O. N., Hamad, N. M. A., Osawaru, B., & Adewusi, O. E. (2024). Enhancing STEM education through emotional intelligence and counseling techniques. *World Journal of Advanced Research and Reviews, 21*(2), 1747–1756. https://doi.org/10.30574/wjarr.2024.21.2.0503

Bardach, L., Klassen, R. M., & Perry, N. E. (2022). Teachers' psychological characteristics: Do they matter for teacher effectiveness, teachers' well-being, retention, and interpersonal relations? An integrative review. *Educational Psychology Review, 34*(1), 259–300. https://doi.org/10.1007/s10648-021-09614-9

Beardsley, M., Albó, L., Aragón, P., & Hernández-Leo, D. (2021). Emergency education effects on teacher abilities and motivation to use digital technologies. *British Journal of Educational Technology, 52*(4), 1455–1477. https://doi.org/10.1111/bjet.13101

Calandri, E., Mastrokoukou, S., Marchisio, C., Monchietto, A., & Graziano, F. (2025). Teacher emotional competence for inclusive education: A systematic review. *Behavioral Sciences, 15*(3), Article 359. https://doi.org/10.3390/bs15030359

Gómez-Pablos, V. B., Matarranz, M., Casado-Aranda, L.-A., & Otto, A. (2022). Teachers' digital competencies in higher education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 19*, Article 8. https://doi.org/10.1186/s41239-021-00312-8

Hrona, N., Khomych, T., Semenog, O., Kharchenko, I., Yurchenko, A., & Semenikhina, O. (2024). Tools for the development of emotional intelligence: Cognitive native language teaching. *International Journal of Instruction, 17*(2), 599–616. https://doi.org/10.29333/iji.2024.17233a

Kharchenko, I. I., & Semenikhina, O. V. (2024). Culture of professional communication and emotional intelligence: Identifying connections. In O. Nestulya, O. Semenog, & M. Shyshkina (Eds.), *Modern educational strategies under the influence of the development of the information society and European integration* (pp. 526–576). Baltija Publishing. https://doi.org/10.30525/978-9934-26-405-4-27

Mhlongo, S., Mbatha, K., Ramatsetse, B., & Dlamini, R. (2023). Challenges, opportunities, and prospects of adopting and using smart digital technologies in learning environments: An iterative review. *Heliyon, 9*(6), Article e16348. https://doi.org/10.1016/j.heliyon.2023.e16348

Navas-Bonilla, C. del R., Guerra-Arango, J. A., Oviedo-Guado, D. A., & Murillo-Noriega, D. E. (2025). Inclusive education through technology: A systematic review of types, tools and characteristics. *Frontiers in Education, 10*, Article 1527851. https://doi.org/10.3389/feduc.2025.1527851

Ng, D. T. K., Wu, W., Leung, J. K. L., Chiu, T. K. F., & Chu, S. K. W. (2023). Design and validation of the AI literacy questionnaire: The affective, behavioural, cognitive and ethical approach. *British Journal of Educational Technology, 55*(1), 140–161. https://doi.org/10.1111/bjet.13411

Rahman, M. H., Amin, M. B., Yusof, M. F., Islam, M. A., & Afrin, S. (2024). Influence of teachers' emotional intelligence on students' motivation for academic learning: An empirical study on university students of Bangladesh. *Cogent Education, 11*(1), Article 2327752. https://doi.org/10.1080/2331186X.2024.2327752

Semenog, O., Hrona, N., Khomych, T., Rozumenko, A., Yurchenko, A., & Semenikhina, O. (2024). Development of emotional intelligence in the system "Teacher–Student–Language Training" based on a communicative approach. *Interdisciplinary Studies of Complex Systems, 25*, 90–110. https://doi.org/10.31392/iscs.2024.25.090

Semenog, O., Hrona, N., Khomych, T., Stasiuk, T., Yurchenko, A., & Semenikhina, O. (2024). Communicative tasks as a means of developing the emotional intelligence of students. *International Journal of Modern Education and Computer Science, 16*(4), 46–57. https://doi.org/10.5815/ijmecs.2024.04.04

Shyshenko, I. V., Chkana, Y. O., Martynenko, O. V., Udovychenko, O. M., Udovychenko, I. M., & Semenikhina, O. V. (2024). The use of digital technologies during the study of mathematical analysis as a basis for the development of students' emotional intelligence in new crisis conditions. In *2024 47th MIPRO ICT and Electronics Convention (MIPRO)* (pp. 346–351). IEEE. https://doi.org/10.1109/MIPRO60963.2024.10569618

Yurchenko, A. O., Mulesa, P. P., & Semenikhina, O. V. (2023). Individual educational trajectory building as a successful teacher skill in the digital age. *Pedagogy and Education Management Review, 2*, 64–72. https://doi.org/10.36690/2733-2039-2023-2-64-72

Zhang, J., & Zhang, Z. (2024). AI in teacher education: Unlocking new dimensions in teaching support, inclusive learning, and digital literacy. *Journal of Computer Assisted Learning, 40*(4), 1248–1266. https://doi.org/10.1111/jcal.12988