Model of primary school teachers’ readiness for implementing STEM education in the era of artificial intelligence

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Abstract

This study examines the readiness of Ukrainian primary school teachers to integrate STEM education with artificial intelligence (AI). A mixed-methods design was applied, combining a literature review, a 28-item survey of 94 teachers, and statistical analyses, including K-means clustering and correlation analysis. The results revealed three teacher profiles: highly motivated with active STEM integration, moderately ready with methodological and resource needs, and low readiness due to limited support. Institutional support and motivation were identified as the strongest predictors of readiness, while technical barriers hinder implementation. Correlation analysis showed that institutional support (r=0.99) and motivation (r=0.99) are the strongest predictors of readiness, while technical barriers (r=-0.98) significantly reduce it. Based on these findings, the study proposes the STEM-AI Readiness Model, which includes five components – technological awareness, pedagogical competence, ethical readiness, motivation, and institutional support – and serves as a framework for targeted professional development and policy planning.

Keywords

STEM education, artificial intelligence, teacher readines, primary school, digital transformation, professional development

1. Introduction

The modern education system is evolving at the intersection of two major global trends: the active implementation of STEM education (science, technology, engineering, and mathematics) and the rapid integration of artificial intelligence (AI) technologies into the learning process. The combination of these areas opens up broad opportunities for improving the quality of education and fostering innovative development among students while simultaneously creating challenges that require rethinking pedagogical approaches and updating teachers’ professional training.

One of the most pressing issues is teachers’ insufficient readiness to implement the STEM approach: a significant proportion of primary school teachers lack adequate knowledge and experience to work with interdisciplinary projects. This makes it difficult to integrate modern technologies into curricula. Additional barriers include limited material and technical resources, a lack of modern equipment and teaching materials, and persistent gender stereotypes in STEM fields [1].

STEM education is particularly important in primary school, as this is the period when the foundations of critical thinking, creativity, research skills, and an engineering approach to problem-solving are laid. Integrating science, technology, engineering, and mathematics helps children learn to analyse information, work in teams, and find innovative solutions. In the digital society, the ability to interact with modern technologies, including AI tools, becomes a key competence [2].

At the same time, integrating AI into education brings challenges related to ethical aspects, data security and confidentiality, and the need for teachers to be prepared for its responsible and effective use.

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Limited technical resources and school infrastructure exacerbate the risks of unequal access to quality education [3]. However, the synergy of STEM and AI opens new prospects: personalised learning, automated assessment, the development of critical thinking skills, and an overall more effective and modern learning process [1].

Artificial intelligence not only enriches STEM education with new tools but also redefines its pedagogical objectives: students are no longer just learners of science and technology but active co-creators working alongside intelligent systems. This conceptual shift is particularly critical in primary education, where the foundations of digital literacy and ethical awareness are formed.

This topic is particularly relevant in the Ukrainian context, as implementing the "New Ukrainian School" (NUS) concept emphasises a competency-based approach, integrated learning, and the development of 21st-century skills. For primary school, this means creating a learning environment where students gain experience with technology from an early age, develop critical thinking, learn to work in teams, and use modern digital tools. STEM education combined with AI technologies can be an effective mechanism for achieving these goals, especially in the context of post-war educational recovery, where it is essential to overcome the digital divide and ensure equal access for all children to innovative opportunities.

This study aims to determine the readiness level of primary school teachers to implement STEM education using artificial intelligence technologies, identify key barriers and motivating factors, and develop a STEM-AI Readiness model that can serve as a basis for teacher professional development programs.

The relevance of this topic is driven by the need to adapt the education system to technological changes, prepare teachers for new challenges, and ensure equal access to innovative educational practices.

This study addresses the following research questions:

1. What is the level of technological, pedagogical, and ethical readiness of primary school teachers to implement STEM education using AI technologies?

2. What are the main barriers and motivators that influence teachers' readiness to integrate STEM and AI into the educational process?

3. Which components of the STEM-AI Readiness model are most effective in supporting teachers' transition from medium and low readiness levels to high levels?

The research hypothesis states that the level of readiness of primary school teachers to implement STEM education with the use of artificial intelligence technologies largely depends on a combination of three factors: (1) technological awareness, (2) pedagogical competence, and (3) institutional support. With adequate support and targeted professional development, these factors can overcome initial barriers (resource and methodological) and ensure teachers' transition from medium and low readiness levels to high levels.

The general hypothesis is detailed into three sub-hypotheses (H1–H3):

H1: A higher level of technological awareness and experience with digital tools directly correlates with readiness to integrate STEM and AI.

H2: Motivational factors (personal interest and student needs) have a greater impact on teachers' readiness than external factors (administrative requirements).

H3: Targeted professional development programs and administrative support reduce the negative impact of technical and methodological barriers on integrating STEM and AI.

2. Analysis of research

In the context of global changes in education, research on teachers' readiness to implement STEM education and artificial intelligence (AI) technologies is gaining particular importance. Recent studies emphasise three key aspects:

- technological and pedagogical preparedness of teachers;

- access to modern resources and infrastructure;
- compliance with ethical standards in the use of AI.

For example, Beege et al. [4] examined the impact of ChatGPT on the educational process in German secondary schools. The authors found that the use of AI among teachers remains limited due to the low level of integration of AI tools into curricula and the absence of official methodological guidelines. Insufficient technological and pedagogical preparedness of teachers continues to be a key barrier to the effective implementation of AI.

Alnasib [5] focused on the readiness of Saudi Arabian university faculty members to integrate AI into their teaching practices. The study revealed that the medium level of readiness is associated with a lack of awareness and limited resources. At the same time, positive attitudes and strong behavioural intentions create potential for further AI integration. Differences in gender, age, and experience highlight the need to adapt training programs for different groups of teachers. Key obstacles include insufficient understanding of AI capabilities, restricted resource access, and weak technological skills.

Bautista et al. [6] used the TPACK model to assess the readiness of preservice teachers (PSTs) to integrate AI. The authors demonstrate that technological, pedagogical, and content knowledge are interrelated and form a basis for ethical and responsible use of AI tools. Despite the generally high readiness level of PSTs, the main barriers remain a lack of technical support and insufficient training focused on the practical application of new technologies.

Papagiannopoulou et al. [7] developed the TRi-STEM scale, which measures teachers' readiness to implement STEM through four parameters: affective conditions, cognitive conditions, self-efficacy, and STEM commitment. This tool has proven effective in assessing readiness regardless of prior teaching experience.

Ayanwale et al. [8] confirm that specialised professional development programs can significantly increase teachers' confidence and readiness to work with AI technologies. Similarly, Alshorman [9] highlights systemic barriers such as outdated infrastructure, limited access to resources, and a lack of practical AI training and stresses the importance of fostering an ethical culture in this area.

Researchers Aguilera et al. [10] proposed the IDEARR model, which integrates epistemological foundations (general systems theory and education reconstruction model) with pedagogical approaches (situated learning and co-teaching). The model was designed to bridge the gap between theory and STEM practice. IDEARR proposes a bidirectional, interactive approach where each STEM discipline retains its identity but interacts with others to solve real-world problems. The roles of each discipline are defined: science provides knowledge, engineering creates innovations, technology assesses impact, and mathematics supports calculations and modelling. The model considers social aspects, including local and global issues. Pedagogical integration is achieved by collaborating with teachers from different specialities (co-teaching). IDEARR aims to address complex real-life problems using an interdisciplinary approach, fostering STEM literacy, STEM thinking, and STEM identity while helping students understand and solve real-world societal problems. It encourages active learning, collaboration, critical and creative thinking, interdisciplinary knowledge integration, and practical skills development. It requires active teacher involvement, access to resources, and adaptation to social contexts, making it applicable in diverse educational environments.

Laksita et al. [11] conducted a bibliometric analysis of Scopus publications from 2003 to 2024, which confirmed the growing global interest in STEM education and its significance. This growth has been particularly evident since 2018, demonstrating global recognition of the importance of STEM education for addressing contemporary challenges. Asian countries (47.52%), including Vietnam, Hong Kong, Turkey, and Malaysia, make the largest contribution to publications, followed by European countries (Germany, Ireland, Greece) and Australia. Key research themes include teacher professional development, technology integration, critical thinking, creativity, and the role of STEM in early education.

Yang et al. [12] showed that even experienced educators need additional support to implement an integrated STEM approach and highlighted the importance of self-efficacy and self-assessment for successful program implementation.

Ukrainian researchers Marushko et al. [13] analysed the readiness of students – future natural science teachers – to integrate STEM. The findings revealed a low level of knowledge, limited resources, and a need for state support. The study recommends developing interdisciplinary courses, expanding practical training, and equipping schools with modern tools. It also confirmed that modernisation of education is possible in response to technological challenges and labour market needs. Most students have a limited understanding of the STEM concept and its application, mainly due to a lack of technical resources. Future teachers indicate insufficient state support and a lack of funding as major barriers to STEM implementation. The study suggests that STEM integration requires a systematic approach:

- developing comprehensive educational programs with an emphasis on interdisciplinary practical training;
- forming STEM competencies in future teachers through specialised programs;
- ensuring state support and funding for educational institutions.

The analysis of sources demonstrates the complexity of integrating STEM and AI into the educational process. The findings highlight the need for a systematic approach to successfully preparing primary school teachers to implement STEM education in new technological realities. Furthermore, despite the accumulated research on STEM and AI, most studies focus on secondary and higher education and do not address the specifics of primary education. There is a lack of an integrated model that simultaneously assesses teachers' readiness for STEM and AI and incorporates an ethical component. Motivational factors, the specifics of the Ukrainian context, and teacher segmentation by readiness levels remain underexplored, emphasising this research's relevance.

Ukraine faces the same key challenges as other countries (technical resources, methodological support, low level of training, and ethical issues). However, the Ukrainian context is further complicated by wartime conditions, unstable infrastructure, and a lack of state support programs, making the problem more acute.

These results confirm the need for systematic studies of primary school teachers' readiness to integrate STEM and AI and the development of a professional competence model adapted to Ukrainian conditions.

3. Research methodology

This study aimed to assess the readiness of primary school teachers to implement STEM education in the context of the growing influence of artificial intelligence technologies. Particular attention was given to identifying the relationships between teachers' knowledge, experience, and readiness and determining key barriers and motivational factors that affect the effective integration of STEM into the educational process.

The research was based on a mixed-methods approach combining a questionnaire survey and a literature review. To collect empirical data, the research team developed a questionnaire consisting of 28 questions organised into four logical blocks:

1. General information about respondents (5 questions).
2. Awareness and experience with STEM and AI (8 questions).
3. Barriers and motivational factors (10 questions).
4. Needs for professional development (5 questions).

The questionnaire employed several types of measurement scales:

- 5-point Likert scale,
- ranking of factors (from 1 to 3 by priority),
- closed-ended questions with single or multiple choice,
- and three open-ended questions for clarification.

The survey collected quantitative and qualitative data from primary school teachers across various regions of Ukraine, reflecting their professional background and current practices. Responses were collected via Google Forms, and all answers were processed anonymously to ensure confidentiality.

A literature review was conducted using publications indexed in Scopus to identify global trends and models of STEM and AI integration into the educational process. In particular, for primary school, we relied on research [12, 14].

The quantitative analysis was based on survey data collected from 94 primary school teachers working in Ukrainian educational institutions. The research instrument was designed to examine aspects such as the level of technical training, knowledge of AI technologies, experience with digital tools, and the influence of these factors on readiness to implement STEM education. The sample included teachers with varying degrees of experience in STEM and AI.

The collected data were analysed using statistical and descriptive methods:

- Correlation analysis to identify relationships between key variables.
- Cluster analysis to identify groups of teachers with different readiness levels for STEM implementation.
- Frequency and mean analysis to determine the main barriers, motivational factors, and priority topics for professional development.

4. Results

4.1. Identification of teacher readiness profiles via cluster analysis

A K-Means cluster analysis was conducted to identify groups of teachers with different levels of readiness to implement STEM education. This method was chosen for its effectiveness in grouping respondents based on the similarity of their survey responses.

The clustering dataset included the main factors influencing teachers' readiness:

- experience with STEM and AI;
- motivational factors;
- the impact of professional development and technical support;
- self-assessment of readiness to implement STEM;
- knowledge level in AI technologies.

Based on these variables, three clusters of teachers were formed (table 1):

- **Cluster 0** – teachers with a moderate level of readiness and partial technical barriers;
- **Cluster 1** – teachers with high motivation and active STEM integration;
- **Cluster 2** – teachers with low motivation or limited technical resources.

Table 1
Distribution of teachers by clusters.

Cluster	Number of teachers	Key characteristics
0	30	Moderate readiness, need for support
1	29	High readiness and active integration
2	35	Low motivation, technical and methodological barriers

4.2. Key results of the clustering analysis

The cluster analysis revealed three distinct teacher profiles, each characterized by specific levels of readiness, motivation, and barriers to implementing STEM education and AI technologies (table 2).

Cluster 0:

- Teachers in this cluster have basic knowledge of STEM and partial familiarity with AI technologies.
- Key barriers: insufficient technical resources (73%) and lack of methodological materials (35%).

Cluster 1:

- Teachers demonstrate strong motivation to implement STEM, driven by students' needs (66
- Almost all of them actively integrate STEM into their teaching practices.

Cluster 2:

- Teachers in this cluster exhibit low readiness due to insufficient administrative support and a lack of technical resources.
- 48% identified inadequate funding as the main barrier.

Table 2
Comparison of key cluster characteristics.

Characteristic	Cluster 0	Cluster 1	Cluster 2
Readiness to implement STEM (5-point scale)	3	4–5	2
Motivational factors	Need for methodological support	Personal interest and students' needs	Low motivation and barriers
Technical support	Insufficient	Partial	Critical deficit
Administrative support	Partial	Full	Limited

The cluster analysis results confirm that teacher groups have different needs and readiness levels for integrating STEM and AI.

- Cluster 1 stands out with a high readiness level (4.5 points), strong administrative support, and low technical barriers.
- Cluster 0 demonstrates moderate readiness but with clear technical constraints.
- Cluster 2 has the lowest readiness and the greatest resource deficits.

Cluster 1 is the most prepared and motivated, supported by active administrative engagement and better resources. Cluster 0 needs additional methodological materials and professional development. Cluster 2 faces serious technical and financial challenges that hinder readiness. These findings emphasise that successful STEM and AI integration requires improved technical resources and consistent methodological support.

4.3. Awareness of STEM and AI

The survey indicates that teachers' awareness of STEM is relatively high: 50% of respondents actively implement STEM practices, while the remaining 50% have a basic understanding of the concept. However, knowledge of AI remains uneven: 60% of teachers report partial understanding of AI, and only 5% use it regularly. The integration of AI into the teaching process remains at a low level.

Key indicators:

1. Understanding AI concepts: 60% have basic or partial understanding.
2. AI use in teaching: 47% occasionally use AI; only 5% regularly integrate AI into their practice.

3. Knowledge of AI fundamentals: 80% believe their understanding of AI fundamentals requires improvement.

These findings emphasise the importance of teacher training in AI.
Survey results show active integration of digital tools:

- Presentation platforms: used regularly by 65% of teachers;
- Data visualisation tools: used by 54%;
- Digital simulations and interactive experiments: 70% report periodic or continuous use;
- Tools for group projects: used in 60% of classes.
- However, the availability of digital tools varies significantly between schools.

4.4. Readiness for STEM implementation

Teachers reported an average readiness score of 3.26 on a 5-point scale. About 57% of respondents rated their readiness as three or higher. The availability of methodological materials and experience with digital tools were found to be key factors influencing readiness. The survey also identified key barriers (figure 1):

- Technical infrastructure: 73%
- Lack of methodological materials: 35%
- Limited administrative support: 48%
- Insufficient knowledge of AI ethics: 40%

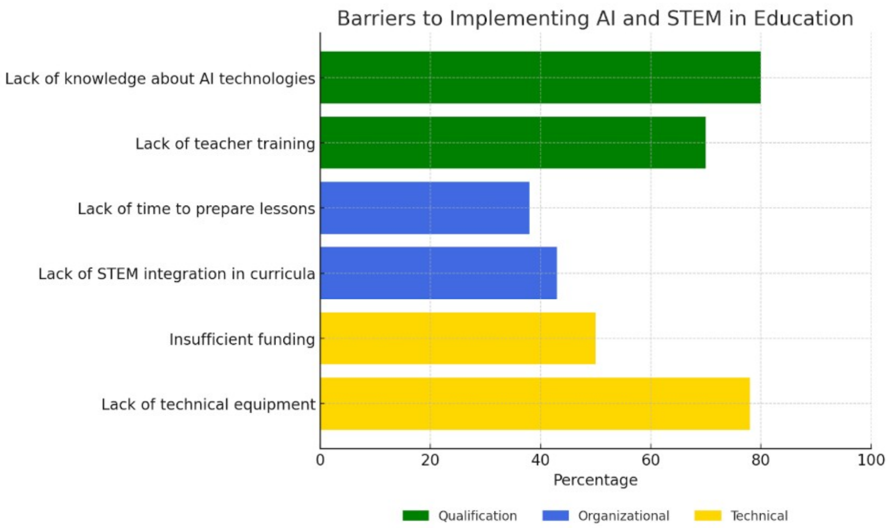

Figure 1: Main barriers to STEM and AI implementation.

Administrative support (average score 3.97) and access to resources correlate strongly with readiness. Professional development programs, mentioned by 73.4% of respondents, are seen as essential for increasing readiness.

The analysis shows that students' needs and teachers' personal interests are the strongest motivators (table 3).

Figure 2 illustrates the most requested topics, which emphasize the need to develop digital competencies and organizational skills for STEM project work.

Although AI technologies are increasingly present in modern education, their integration remains limited:

Table 3
Main motivational factors.

Factor	% of responses
Students' needs	70.21%
Personal interest	67.02%
Administrative requirements	3.19%

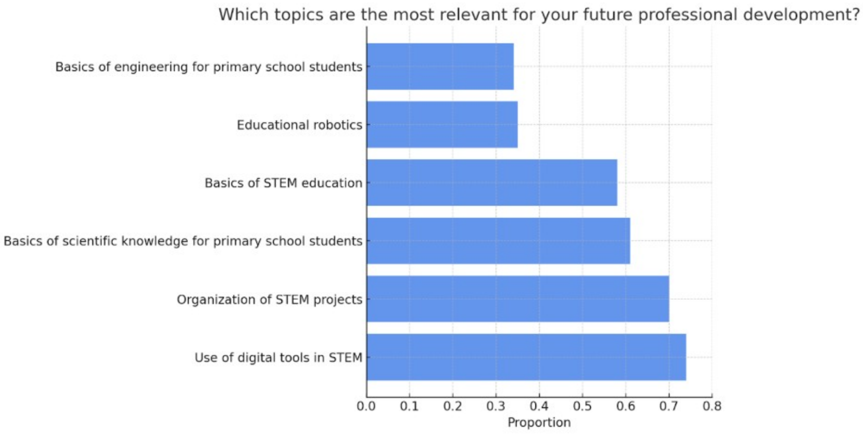

Figure 2: Key topics for professional development.

- 5% of teachers use AI regularly,
- 47% report occasional use for specific tasks (e.g., creating materials, data analysis),
- 26% have not yet used AI but plan to do so (figure 3).

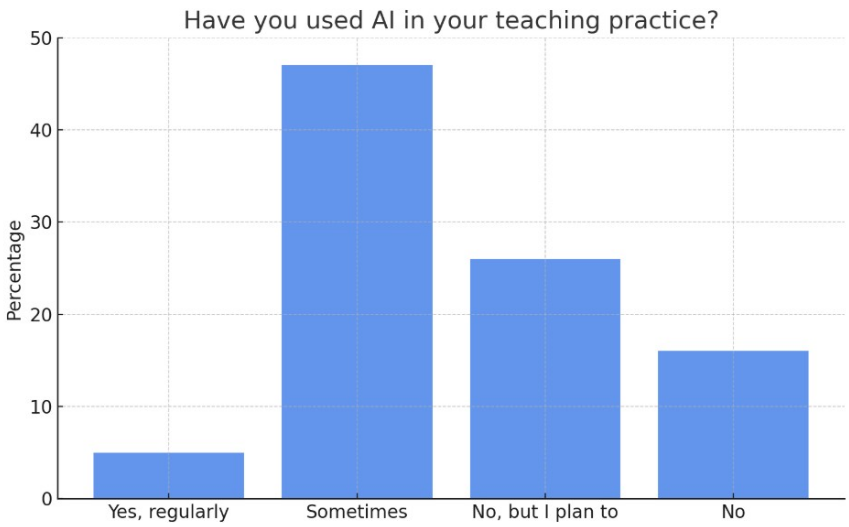

Figure 3: Teachers' responses on AI use in their practice.

These findings indicate a transitional stage between exploration and consistent use of AI in teaching.

Teachers are particularly in need of foundational knowledge and methods of integrating AI into different aspects of teaching (table 4).

Teachers emphasize:

- data privacy concerns (50%);
- risks of academic dishonesty using AI tools (35%);

Table 4
Teachers' self-assessed AI competence.

Competence area	% reporting need for improvement
AI fundamentals	80%
Using AI to create materials	67%
Integrating AI for learning analytics	75%
Ethical aspects of AI use	40%

- the importance of explaining AI principles to students (40%).

The correlation matrix (figure 4) shows:

- Administrative support: strong positive correlation with readiness (r = 0.99);
- Motivation: strong positive correlation with readiness (r = 0.99);
- Technical barriers: strong negative correlation with readiness (r = -0.98).

Readiness	1,00	-0.98	1,00	0,99
Technical barriers	-0.98	1,00	-0,99	0,95
Administrative support	1,00	-0,99	1,00	0,98
Motivation	0,99	-0,95	0,98	1,00
	Readiness	Technical barriers	Administrative support	Motivation

Figure 4: Correlation matrix of factors.

Even with high motivation, insufficient resources and lack of support significantly reduce readiness.

5. Discussion

The survey of 94 Ukrainian teachers shows that 50% actively integrate STEM, while the rest have only basic understanding. AI use remains low – only 5% of teachers use it regularly, despite 60% having partial understanding. The average readiness level is 3.26 out of 5.

International studies (Beege et al. [4], Bautista et al. [6], Alnasib [5], Ayanwale et al. [8], among others) confirm similar findings: teachers in Germany, Saudi Arabia, and the Philippines also show moderate readiness, limited practice, lack of resources, and the need for professional development. However, there is a growing trend in motivation and awareness of the importance of STEM and AI. The Ukrainian findings mirror global challenges (table 5).

Table 5
Barriers to STEM and AI implementation.

Ukraine (survey)	International studies
Insufficient technical resources (73%)	Lack of resources, unstable Internet (Alshorman, 2024)
Lack of methodological materials (35%)	Lack of structured models (Beege et al., 2023)
Limited administrative support (Cluster 2)	Misalignment with curricula (Ayanwale et al., 2024)
Insufficient knowledge of AI ethics	Need for ethical training (Bautista et al., 2024)

Based on these findings, a STEM-AI Readiness Model was developed, which includes five key components:

- **Technological awareness** – knowledge and skills in using digital tools, STEM resources, and basic AI technologies.
- **Pedagogical competence** – the ability to integrate STEM into the learning process through innovative and interdisciplinary approaches.
- **Ethical readiness** – understanding risks related to data privacy and academic integrity, and awareness of responsible AI use.
- **Motivation and attitude** – openness to innovation and a student-centered mindset.
- **Institutional support** – access to technical resources, methodological materials, and administrative support.

The model allows segmentation of teachers into three levels of readiness: low, medium, and high (table 6).

Table 6
Empirical scale of STEM-AI readiness.

Component	Low level (%)	Medium level (%)	High level (%)
Technological awareness	20	25	30
Pedagogical competence	15	25	30
Ethical readiness	10	15	20
Motivation & attitude	30	20	10
Institutional support	25	15	10

The model reflects that at low readiness, external motivators dominate and institutional support is lacking. At the medium level, components become balanced, with increasing technological and pedagogical elements. At high readiness, competence and self-sufficiency prevail.

The proposed model can serve as a diagnostic and strategic tool for educational stakeholders. Readiness diagnostics enable the identification of teacher profiles and help prioritize directions for professional development.

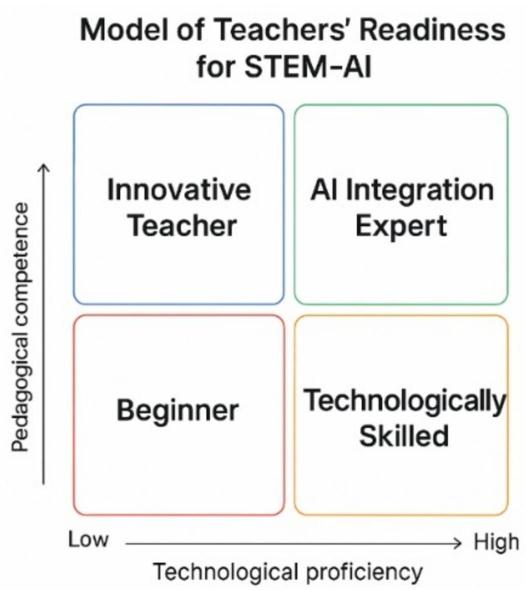

Figure 5: The STEM-AI readiness model.

Figure 5 illustrates the STEM-AI Readiness Model for teachers, structured as a two-axis diagram. The vertical axis represents pedagogical competence, while the horizontal axis reflects technological proficiency. Depending on these two dimensions, teachers are categorized into four groups: Innovative Teacher, AI Integration Expert, Beginner, and Technologically Skilled. This visual model highlights how varying levels of skills and knowledge position educators differently in terms of readiness to integrate STEM and AI into teaching practice.

Targeted development programs should be aligned with readiness levels:

For the low readiness group, the focus should be on basic training in digital tools and the use of fundamental STEM and AI resources.

The medium-level group would benefit from participation in methodological workshops, subject-specific training, and structured mentoring initiatives.

Teachers at the high readiness level should be engaged in innovation-oriented training, leadership in digital education, and peer-to-peer mentoring to support colleagues.

In addition, policy-level support is essential and may include sustained funding, the development of national online platforms for STEM-AI integration, and systems for interschool knowledge exchange.

The model facilitates personalized and systemic support, helping reduce inequalities in access to innovative educational resources and accelerating the implementation of STEM and AI in primary school curricula.

The effective implementation of the STEM-AI Readiness Model requires a combination of short-term measures at the school level and long-term strategies at the level of educational policy. In the short term, the priority actions are those directly aimed at increasing teacher readiness. For teachers with low readiness, the primary task is basic training in digital tools and the use of fundamental STEM and AI resources. Teachers at the medium level of readiness benefit most from methodological workshops, subject-specific training, and structured mentoring, while those at the high level require engagement in innovation-oriented training, leadership initiatives in digital education, and peer-to-peer mentoring. An essential component of this stage is also the provision of open-access online resources with practical materials, case studies, and lesson templates. These measures are the most feasible and impactful in the short term, as they address immediate barriers and establish a foundation for further growth.

In the long term, the priority shifts to systemic actions at the policy level that create conditions for sustainable integration of STEM and AI. Such measures include investments in infrastructure (modern equipment and stable internet access in schools), sustained funding, the development of national platforms for STEM-AI integration, and systems of interschool knowledge exchange. Equally important is the inclusion of STEM and AI courses in teacher education programs, the integration of the TPACK framework into professional development, and the introduction of AI ethics modules into teacher training. Strengthening school-level administrative leadership also plays a crucial role, as management largely determines the sustainability of innovative practices.

Thus, short-term actions at the school level provide a rapid and tangible increase in teacher readiness, while long-term policy strategies ensure systemic conditions for sustainable STEM-AI integration. The complementarity of these two levels of action allows for reducing educational inequalities and accelerating the digital transformation of primary education.

Unlike traditional STEM-readiness frameworks, the proposed STEM-AI Readiness Model explicitly incorporates ethical readiness as a core dimension, acknowledging that AI technologies reshape not only the tools but also the values and responsibilities of STEM education.

6. Conceptual expansion

Although the STEM-AI Readiness Model was developed in the Ukrainian context, its structure allows for adaptation across diverse educational systems. The five-component framework – technological awareness, pedagogical competence, ethical readiness, motivation, and institutional support – can be scaled to reflect local priorities and resource availability. For example, in countries with advanced digital infrastructure, emphasis may shift toward ethical readiness and pedagogical innovation, while in resource-constrained contexts, technological access and institutional support would remain the primary focus. Such flexibility makes the model applicable as both a diagnostic tool and a strategic guide internationally.

Moreover, teacher training institutions could integrate the model into certification pathways or microcredentialing programs. Embedding its components into pre-service curricula and in-service professional development would allow teachers to progress through clearly defined levels of readiness. Microcredentials in areas such as AI ethics, STEM pedagogy, or digital leadership could provide evidence of competencies aligned with the model, offering teachers both recognition and motivation for continuous growth. This approach would not only standardize expectations but also promote the systematic development of teacher capacity in STEM and AI integration across educational systems.

7. Conclusions

This study highlights the moderate but uneven level of STEM-AI readiness among Ukrainian primary school teachers. The variability in readiness is strongly influenced by contextual factors, particularly the availability of technical resources and the degree of institutional support. The most significant barriers to implementation include limited access to equipment (73%) and a shortage of methodological materials (35%), which impede the integration of STEM and AI into everyday teaching practice.

Correlation analysis confirms that teacher motivation and institutional backing are critical drivers of readiness. Furthermore, the ethical use of AI and digital literacy emerge as underdeveloped but essential components that should be systematically embedded in professional development programs.

The STEM-AI Readiness Model proposed in this study serves not only as a diagnostic tool but also as a strategic framework for targeted teacher support. It can inform the design of differentiated training pathways and help overcome specific barriers at various levels of teacher preparedness.

Comparative insights from Ukrainian and international data reveal common global challenges: insufficient practical training, technical limitations, and ethical uncertainty. Nevertheless, the high level of teacher motivation and the worldwide momentum toward digital transformation present valuable opportunities. Addressing these challenges requires a systemic, multi-level strategy that integrates professional learning, resource provision, and clear ethical guidance to foster an innovative and future-ready school environment.

For the effective integration of AI into teaching practice, it is necessary not only to raise teachers' technical awareness but also to ensure they have adequate resources and incentives for using AI. To enhance teachers' readiness at different levels, the following actions are recommended:

- Develop professional development programs that include practical training in STEM with the use of AI, emphasizing its significance and benefits.
- Introduce full-scale courses on the use of STEM and AI tools at the university level.
- Provide state support through funding and the development of strategies for implementing STEM education in primary schools.
- Conduct further research with larger samples and focus on introducing STEM tools into real educational practice.
- Promote positive attitudes toward AI through examples of successful practices.
- Improve access to STEM lesson examples, modern AI resources, and ensure reliable internet connectivity.
- Ensure equitable access for primary school teachers through targeted initiatives that address gender barriers and support educators with lower levels of prior training.

Author contributions

Conceptualization: Olha V. Barna; Methodology: Olha V. Barna; Formal analysis: Mariia A. Boiko; Investigation: Mariia A. Boiko; Data curation: Mariia A. Boiko; Writing – original draft: Nataliia V. Morze; Writing – review & editing: Olha V. Barna; Supervision: Nataliia V. Morze; Project administration: Nataliia V. Morze All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data presented in this study are openly available in Google Sheets at the following link: https://docs.google.com/spreadsheets/d/1qVhHiruS2k9ZlUXlrTvFN5qY0rIgYO5cv1KM3ZFgWe0/edit?usp=sharing

Conflicts of interest

The authors declare no conflict of interest.

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Declaration on Generative AI

The authors have not employed any Generative AI tools.

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