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Board 165: K-12 STEM Teachers' Perceptions of Artificial Intelligence: A PRISMA-tic Approach (Work-in-Progress)

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K-12 STEM Pre-Service Teachers' Perceptions of Artificial Intelligence: A PRISMA-tic Approach (Work-in-Progress)

Abstract

Recent technological advancements have led to the emergence of generative artificial intelligence (GenAI) applications like Gemini and ChatGPT. Consequently, these applications of AI and others have proliferated aspects of daily life. Notably, there is a growing interest in incorporating AI to enhance K-12 science, technology, engineering, and mathematics (STEM) education and research. To be effectively integrated, however, AI usage needs to align with teachers' existing STEM curriculum and pedagogy. In essence, the extent to which AI will be deployed in future classrooms will heavily depend on teachers' perceptions of its utility within the STEM education context. STEM teachers' attitudes, expectations, and perceived challenges regarding AI can significantly influence their willingness to adopt AI-integrated instruction approaches. Identifying and categorizing teachers' beliefs, motivational factors, and areas of concern will provide practical insights for STEM curriculum designers, professional developers, and policymakers. This study investigates these possible directions through a lens of major established models of integrated STEM education. Although extensive research has been done on integrating AI with STEM, work is lacking that translates this concept into concrete entry points for integration. To address this gap, this research uses a systematic literature review (SLR) approach focusing on preservice teachers' (PSTs') perceptions of AI in STEM education. Using the PRISMA model, we gathered related empirical, peer-reviewed articles published from 2020 to 2024. Of the 250 initial studies, 26 met our eventual criteria. Content analyses of these surveys revealed several aspects that may be used to further understand PSTs' perspectives on AI's involvement and potential usage in integrated STEM. Firstly, their competency using AI tools appears to greatly influence their attitude toward AI-integrated STEM pedagogy. Second, their perceptions of AI's effectiveness, utility, and ethics seem to significantly impact their willingness to adopt AI for classroom usage. Lastly, research suggests that PSTs recognize both the benefits, like improving student engagement and personalized learning, and the challenges posed by technical difficulties or the complexity of interspersing these technologies in their STEM classrooms. As such, teacher education related to meaningfully using AI tools is an important focus of integrating AI. Teachers must be skilled and confident in using AI tools in their classrooms, while also able to recognize its limitations and potential pitfalls. PSTs, therefore, need access to targeted AI resources and opportunities for application within their STEM pedagogy courses. Meeting these goals means providing teacher educators and researchers with ongoing support to advance the integration of AI into K-12 STEM education.

Keywords: STEM education, artificial intelligence, pre-service teacher, systematic literature review

Introduction

Incorporating artificial intelligence (AI) into interdisciplinary science, technology, engineering, and mathematics (STEM) education represents a drastic but timely shift in established STEM teaching practices (Eugenijus, 2023). Realizing the innovative capacity of AI within existing STEM teaching approaches) means recognizing AI-driven platforms and tools as catalysts for fostering learning environments that are both personally engaging and equitable (Bozkurt, 2023; Pratama et al., 2023). Within this context, teachers are central to the meaningful infusion of AI within STEM classrooms (Al Darayseh, 2023; Dai et al., 2023). Current research shows that teachers' sense of self-efficacy as curricular enactors significantly impacts their ability to provide learners with effective STEM instruction (Hammack et al., 2024). Specifically, teachers' attitudes, understandings, and openness to use AI technologies deeply impact the extent of classroom integration (Choi et al., 2023). This impact is pronounced among preservice teachers (PSTs), whose differing levels of exposure and capacities to use AI technologies can drastically affect their STEM enactment (Polly et al., 2023). Hence, ensuring that teachers are well-prepared and receptive to applying AI tools in STEM instruction will be critical to optimizing the benefits of AI in STEM education (Nnadozie & Okoye-Ogbalu, 2023).

Investigations into AI's role in STEM education appear to be the intersection between technology and pedagogy (Morze & Strutynska, 2023). This focus is particularly relevant for K-12 educators, where learners' foundational skills in STEM are established. In recent years, there has been a spike in studies focusing on the impact of AI on educational outcomes, teacher-student interactions, and curriculum development (Alam, 2021; Guilherme, 2019). However, a notable gap exists in understanding how PSTs, the prospective implementers of these curricular changes, perceive and interact with AI tools (Lee et al., 2023). Their attitude, reservations, and expectations are pivotal in shaping the future of AI-integrated STEM education (Van et al., 2023). This study focuses on the perceptions of PSTs to provide insights into the integration of AI into STEM education, aiming to enhance rather than complicate the teaching and learning process (Nnadozie & Okoye-Ogbalu, 2023).

The theoretical framework for this study is anchored in the eight models of integrated STEM education, as presented by Roehrig et al. (2021). These models offer an organized approach to examining the integration of AI into STEM education. The PRISMA model was used in this study to select the studies included in this review. This approach is highly corroborated and recognized for its thorough and rigorous method for literature review and data analysis (Shamseer et al., 2015). The stringent requirements of the PRISMA model ensure a comprehensive and objective analysis of empirical research. This study explores PSTs' perceptions of integrating AI into STEM educators by analyzing the selected studies to identify key themes and challenges of integrating AI into STEM education.

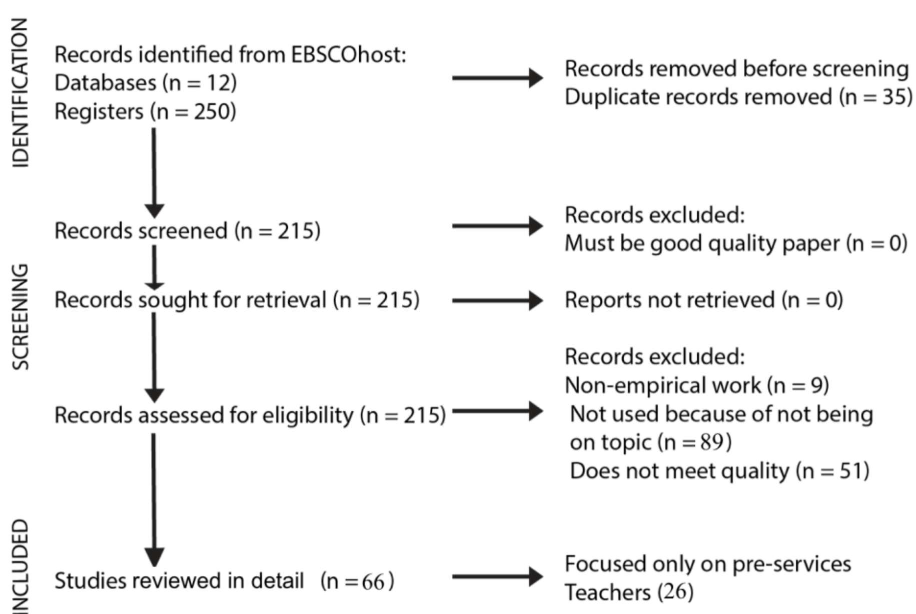
The following are the research questions of this study:

1. What are PSTs' attitudes towards AI-integrated STEM education, and what factors influence this perception?
2. What are the defining factors that affect PSTs' readiness and willingness to integrate AI into their pedagogical strategies?
3. How do findings inform the development of future teacher training programs in integrating AI into STEM education?

Methodology

This systematic literature review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) model, a globally recognized standard for conducting and reporting systematic reviews (Shamseer et al., 2015). The PRISMA model is characterized by its comprehensive 27-item checklist and a detailed four-stage flowchart, which collectively ensures the review process's integrity, transparency, and methodological rigor. Our systematic review was guided by a structured search strategy to identify scholarly works regarding AI, perception science, and teacher education, with a pronounced focus on elementary education and teacher training programs. These databases included, but were not limited to, Web of Science, Scopus, IEEE Xplore, ERIC, JSTOR, ScienceDirect, SpringerLink, Wiley Online Library, SAGE Journals, Academic Search Premier (EBSCOhost), ProQuest, arXiv, and Google Scholar. Search terms include "AI" and "Perception Science," around which we built a constellation of related educational and technological terms such as "Elementary School," "Teacher Education," "Teacher Trainee," "Pre-service," "Generative AI," "Technology Education," "Professional Development," "Engineering Education," and "Mathematics Education."

Figure 1. *The overall architecture of the SLR according to the PRISMA model*



Initially, 250 records were identified from various databases and registers. Before screening, 35 duplicate records were removed, leaving 215 records. After an initial screening, 9 records were excluded for not being academic or journal papers, leaving 206 records for retrieval. From these selected studies, 89 records were not fully relevant to the focus of this study and were therefore not retrieved. The rest of the 118 records were evaluated for eligibility, with a further 51 records being eliminated due to particular exclusion criteria not stated in the graphic. The screening procedure resulted in 66 papers that met all the criteria except for focusing on pre-service teachers. Upon refined selection for papers focused on pre-service teachers, 26 papers were selected for inclusion in this systematic review. This thorough methodology assures that the analysis is based on high-quality, relevant, empirical research that directly contributes to the research questions under consideration. The overall architecture of the implemented methodology is provided in Figure 1.

Table 1. *Inclusion and exclusion criteria of the papers*

Inclusion Criteria	**Exclusion Criteria**
Empirical study	Non-empirical and theoretical studies
Focused on K–12 education	Others, such as college education, adult education
Written in English	Written in other languages
Studies used unplugged tools or methods.	Studies used programming elements (i.e., visual programming, computer, and other plugged-in tools),
Peer-reviewed journal articles, conference papers, or book chapters.	Other publications (e.g., reports, dissertations, narrative papers)
Available in full-text	Not available in full-text
Published between 2020 and 2024	Published before 2020
Pre-service Teachers	In-service teachers

In line with the PRISMA model, the initial pool of studies was subjected to a screening process. We used the inclusion criteria to gather studies that were empirical, peer-reviewed, in English, and on AI and STEM education from teachers' perspectives. Moreover, the articles focused only on K-12 education were peer-reviewed articles and should be available in full text. We included those studies published between 2020 and 2024. This publication range was chosen to reflect the most current AI applications and practices being used in educational contexts and to capture the latest related best practices. We then established exclusion criteria to omit any study that failed to meet inclusion benchmarks. These included studies that were non-empirical, outside the specified timeframe, and not written in English. Each selected study was initially evaluated for its relevance to the topic through reading the titles and abstracts, ensuring it met the quality standards established by the PRISMA criteria. PRISMA guidelines were also used to accurately reference and cite all sources. However, as with any systematic review, this work was limited by the included search terms and databases. Search terms may have impacted the number of articles included.

A two-phase analytical approach was used to code and categorize the eligible studies. Articles were first categorized based on publication date and level of education (i.e., elementary, secondary, postsecondary, or a combination of these). Then, a more in-depth analysis of the articles was done, including or excluding them based on: PSTs' perceptions, the type of AI-enabled tools and PSTs' resulting understandings, and PSTs' educational expectations of these AI-enabled technologies.

Analyzing the educational objectives outlined in the studies provided insights into where AI technologies could be most successfully deployed in teacher education (e.g., entry points and areas of interest). We also focused on PSTs' perceived value of implementing AI technologies, exploring the motivation that drives their intended adoption in educational contexts. This analysis served to unearth the contributing factors influencing the adoption of AI-integrated STEM education and offered insights to how to best support PSTs through their teacher education curriculum.

Findings

Using a mixed methods approach, the results are organized according to qualitative and quantitative analyses, respectively. This organization also reflects the research questions: what perceptions and attitudes related to AI usage contribute to PSTs' consideration of it as an educational tool? Implications are provided in the ensuing discussion.

Qualitative Findings

First, we analyzed the 26 empirical studies to better understand PSTs' perceptions of AI integration into STEM education. This qualitative analysis focused on identifying PSTs' perceptions, experiences, and challenges in considering adopting and implementing AI within STEM lesson plans. The results revealed several unique themes that are summarized below.

Opportunities and Concerns in AI-integrated STEM education

The first theme that emerged was the collective agreement among PSTs for more proactive use of AI tools in teaching methodologies. According to Kannan (2022), for example, AI tools can help teachers accommodate the diverse needs of learners through creating personalized learning resources, leading to better support for teachers in identifying and addressing their specific needs. Eyüp and Kayhan (2023) also highlight note that PSTs are particularly receptive to utilizing these AI tools to support innovative teaching approaches and enhance student engagement. Peres et al. (2023) further discussed AI's potential in supporting teachers in these ways (e.g., personalized learning, aiding in the uptake of innovative practices), emphasizing the importance of preparing the future generation with the necessary skills to leverage modern technologies in the classroom. These insights are particularly relevant when considering the goal of enhancing AI training programs for PSTs to better prepare PSTs for the future demands of teaching; further inclusion of meaningful usage of educational technologies (Ellis et al., 2020).

Furthermore, the benefits of AI-integrated education also benefit PST learning. For instance, Chiu (2023) highlighted the effectiveness of AI-powered tools, such as virtual and augmented reality, in creating more engaging and realistic PST learning environments. This capability not only makes STEM learning more engaging but also increases learners' understanding of its application in real-world contexts, which is crucial for effective learning. However, Zheng et al. (2023) proposed a model to assist PSTs in effectively leveraging AI technologies in educational settings. More importantly, this model demonstrates that these AI tools can complement educational strategies without complicating or replacing the human aspects of teaching. On the other hand, Vartiainen et al. (2022) urge caution in adopting AI within education, pointing out the lack of concrete evidence to support the long-term benefits of AI in student learning outcomes.

Similarly, Abulibdeh et al. (2024) express concerns that over-reliance on AI could lead to a uniform approach to education, which could potentially limit creativity and innovation in seeking more effective teaching pedagogies. However, Ponomareva (2023) offers a balanced view on this matter, proposing a framework for AI integration that emphasizes teachers' critical role in lesson delivery and pedagogical strategies within the classroom. One of the key findings of this study was the need for professional development programs to provide PSTs with the necessary skills for effective AI integration. This approach positions AI as a tool that complements, rather than replaces, traditional teaching methods. Aligning with this advice, Avsec et al. (2021) echo previous sentiments about AI technologies, calling for a more thoughtful and careful implementation to ensure that its deployment remains practical and thoughtful.

PSTs' Attitudes and Perceptions Toward AI

Research by Xu et al. (2022) explored the willingness of PSTs to embrace AI technologies in educational settings. Their findings indicate a generally positive trend toward integrating AI tools in future classrooms. This enthusiasm is fueled by the recognition of AI's capabilities to personalize learning and streamline educational processes (Dey & Jana, 2023). However, the positive sentiments are not universal, as evidenced by studies from Piedade et al. (2021) and Kim and Kim (2022). Their investigation noted a counter-narrative, highlighting educators' reservations about the challenges of AI implementation, such as the need for substantial professional development and concerns over job security (Sungur Gül & Saylan Kirimzigul, 2023).

Such apprehensions point to a need for more comprehensive support systems to facilitate the smooth adoption of AI in educational settings, such as assessment (Gresse von Wangenheim et al., 2022). Additionally, İçen (2022) discussed the impact of the varied attitudes toward its adoption in schools, suggesting a need for targeted efforts to build teacher confidence in using AI tools. Moreover, Kim (2023) synthesizes these perspectives to reveal numerous factors that impact teacher readiness and attitudes toward AI, such as technological competency, institutional support, and PSTs' perception of AI's value (Kim, 2023).

PSTs' Concerns and Reservations About AI

Ethical and privacy concerns are widely discussed in the research. PSTs are particularly concerned about issues such as data privacy, the black box AI algorithms, and potential biases (Incerti 2020), proposing that AI-integrated education should be guided by explicit ethical criteria in its deployment (Jones et al., 2020). Similarly, Schwichow et al. (2022) investigated the ethical aspects of AI in education, calling for clearer regulations that address the transparency of algorithms and data privacy (Krug, 2023). Additionally, Tanase et al. (2023) highlight the need for governmental support in training educators with the necessary skills and expertise to utilize AI technology effectively. On the future of education, Lim (2023) offered perspectives on incorporating AI into education, highlighting the technology's ability to personalize learning experiences and improve fairness and accessibility.

Quantitative Findings

Per quantitative analysis and findings, we provide various figures, 1 through 5, to provide the results descriptively and illustratively based on the 26 eligible studies incorporating AI into preservice teacher education focusing on STEM education. The data is categorized, sorted, and evaluated according to publication years, subjects addressed, and PSTs' perspectives. The first part of the quantitative analysis looks at the distribution of articles according to their publication year. Figure 2 shows that the year 2023 was increased with relevant studies. One of the causes could be attributed to the widespread availability of AI technologies like ChatGPT by late 2022. Additionally, Figure 3 shows the themes that are most pertinent concerning AI in STEM. Yellow color shows the most relevant and foundational themes, followed by green and then purple. Hence, the most salient issue to focus on would be AI's impact on pedagogy.

Figure 2. *Percentage of papers per year for the selected studies*

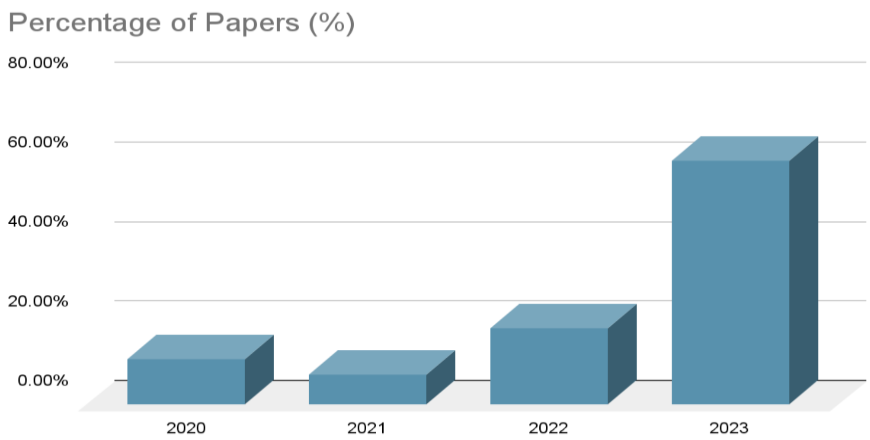
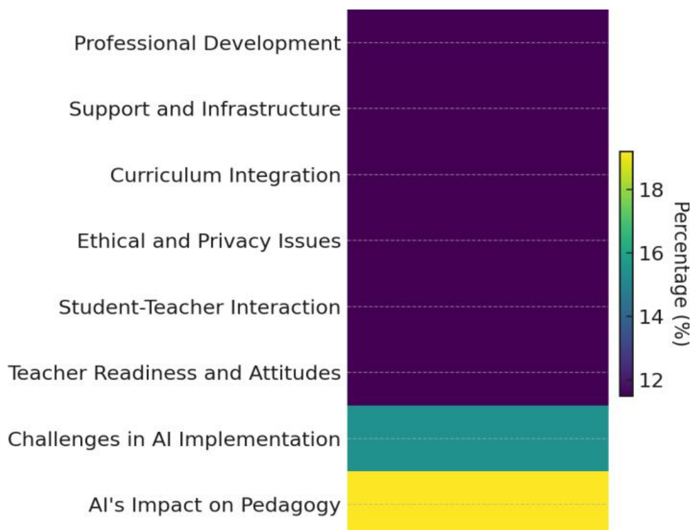


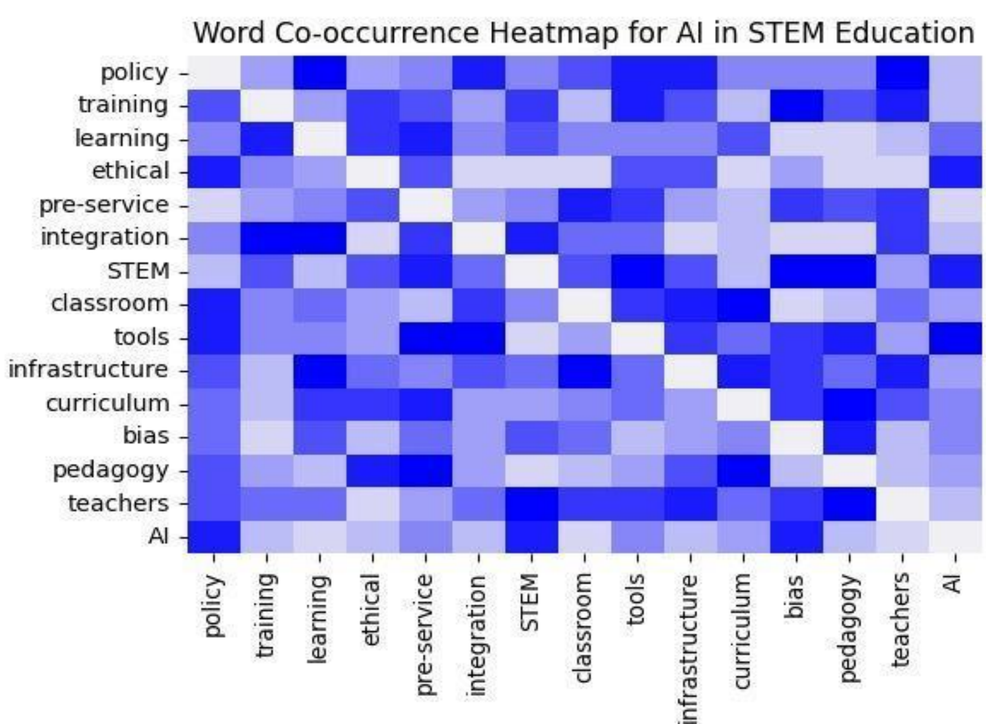
Figure 3. *Thematic distribution of AI in STEM*



We performed a thematic analysis of the content extracted from the selected studies using natural language processing (NLP) libraries to generate a word cloud. The deeper colors show areas of greater focus, such as "STEM," "AI," and "Pre-service," indicating these are key areas of interest and discussion. On the other hand, terms like "Ethics," "Fairness," and "Bias" are also highlighted, along with a slightly lesser intensity, reflecting their significant but secondary role in the research. Terms like "Pedagogy," "Training," and "Classroom" also show the pedagogical considerations in the utilization of AI for the enhancement of learning outcomes. Figure 4 demonstrates a word cloud that displays the words that appear in the selected areas with high frequency. The larger the font of the word, the higher the frequency.

Figure 4. *The word cloud displays key areas of interest*

Figure 5. *Word co-occurrence for AI in STEM education*



Additionally, the heatmap in Figure 5 above visually represents the co-occurrence of key terms related to AI integration with STEM education. The color intensity varies from white to blue, with darker colors showing stronger associations of words together. For example, "AI" and "STEM" appeared in darker shades, reflecting their central role in the topic. On the other hand, other terms occurred together but with lower frequency, indicating lesser emphasis on PSTs within the context of AI in STEM. Adding to this, we observe the co-occurrence of the word “preservice” with other critical terms such as “classroom,” “tools,” “teachers,” and “bias,” signifying PST recognition of AI tools as an amplifier of both positive and negative classroom practices. These relationships offer valuable insights for stakeholders and reveal focal points that need to be prioritized within teacher training programs.

Discussion

In addressing the research questions outlined in the earlier sections, the current literature indicates that PSTs generally perceive AI as a valuable tool. This consensus is partly based on recognizing AI's potential to complement existing educational methodologies and offer a more personalized approach to education. However, Heath et al. (2022) cautioned against an overdependence on technology to prevent constraining future innovations (Heath et al., 2022). Although this advanced technology offers new possibilities for teaching and learning, AI integration should not replace conventional teaching techniques (Ponomareva, 2023). Next, research suggests that offering more comprehensive support with using AI tools in class will significantly increase PSTs' willingness and readiness to integrate these technologies into their practice (Herrero et al., 2023). As PSTs' educational and experiential background influences their openness to integrate AI into the classroom, it is important they have opportunities to do so as they transition from learners to teachers and beyond (Polly et al., 2023).

Moreover, given the interdisciplinary nature of STEM education, AI training throughout teacher education programs could help break down the traditional barriers between theoretical understanding and real-world applications in these subjects. For instance, PSTs could practice integrating AI applications into their lesson plans and field experiences. Radloff et al. (2023) noted the influence of teachers' epistemological understanding and its potential effect on teacher's teaching effectiveness. Considering this observation, enhancing teachers' proficiency in AI tools should support more authentic teaching strategies and bridge AI usage with project-based learning and real-life problem-solving, in turn enhancing the student learning experience and improving educational outcomes (Yang et al., 2024) and assessment practices (Gresse von Wangenheim et al., 2022).

Finally, we address the question of what strategies can be put in place by educators to support PSTs in utilizing AI tools effectively in STEM education. To support PSTs, policymakers and educational institutions will need to establish frameworks and regulations that ensure ethical and sustainable AI integration. These initiatives must include a consideration of AI's technical and moral dimensions. While able to accommodate students with learning disabilities and cultivate inclusive learning environments through personalized learning, as with introducing any educational technologies (Krutka et al., 2023), other unintended outcomes can also emerge. More needs to be known about the intended and unintended consequences of incorporating AI into PST education. Additionally, there is a notable lack of information regarding PSTs' knowledge and beliefs about assessment methods (Lin et al., 2022) that could contribute. As such, incorporating PSTs’ perspectives in the formulation of these new frameworks and regulations is essential.

Conclusion, Implications, and Future Directions

This study’s investigation into PSTs’ perceptions of AI integration in STEM education reveals a positive yet cautious outlook for AI tools to enhance learning experiences in STEM education. Studies suggest that PSTs are largely optimistic about AI’s potential in complementing and advancing existing teaching pedagogies. However, their readiness and willingness to integrate AI into their pedagogical strategies is first contingent upon the availability of AI-related training opportunities and ongoing governmental and institutional support for integration. New guidelines for AI use could contribute significantly to mitigating PSTs’ concerns and encourage the adoption of AI tools into their pedagogical strategies. Furthermore, considering the positive impact of AI-integrated lesson plans on student engagement, effective deployment of these tools can significantly aid in supporting PSTs in understanding the interdisciplinary nature of STEM subjects.

More importantly, in this nascent stage of AI-integrated STEM education, continuous professional development programs focused on increasing competencies in utilizing AI will sharpen PSTs’ critical thinking skills to ensure that such technologies are deployed judiciously in various teaching contexts. Future research on AI-integrated STEM education should consider including longitudinal studies to assess teachers' attitudes, perceptions, and willingness before and after AI training to determine the impact and effectiveness of these programs. Finally, to address the ethical concerns of AI tools in the classroom, establishing a bi-directional relationship between various scientific, educational, and governmental organizations will create a virtuous feedback loop to ensure effective communication and integration of AI tools into STEM pedagogy. This collaborative network among key stakeholders will serve to support equity and accessibility in education and create a more inclusive learning environment for all future learners.

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