Artificial Intelligence (AI) and Industrial Revolution (IR) 4.0 Readiness for Teaching and Learning Competency among 21st Century Pre-Service History Teachers in Sabah

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Abstract

This concept paper investigates the readiness of pre-service History teachers in University Malaysia Sabah to integrate Artificial Intelligence (AI) and Fourth Industrial Revolution (IR 4.0) technologies into their teaching practices. It addresses the current gap between national policy ambitions and practical implementation, especially within non-STEM disciplines like history. Using a mixed-methods approach, the research applies three key theoretical frameworks including Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK), and the AI Readiness Framework. Findings are expected to reveal moderate readiness levels, with notable disparities in infrastructure, faculty support, and tailored training. The study contributes a validated conceptual model and offers policy, curriculum, and professional development recommendations to improve digital competency among history teacher trainees. This work aims to ensure that history education remains relevant and resilient in Malaysia's digital future.

Keywords: AI Readiness, IR 4.0, Pre-Service History Teachers, Teaching Practices

Introduction

The rapid evolution of Artificial Intelligence (AI) has increasingly redefined how knowledge is accessed, constructed, and disseminated. Globally, the Fourth Industrial Revolution (IR 4.0) has initiated a wave of transformation that demands new teaching and learning paradigms. In Malaysia, this technological shift presents unique implications for public universities, particularly for teacher education programs that must prepare graduates for the challenges of 21st century classrooms. The integration of AI into these programs is no longer optional. It is essential for nurturing future educators capable of fostering digital fluency, critical thinking, and collaborative engagement in increasingly automated environments (Goh et al., 2025).

As educators adapt to this transformation, it becomes imperative to examine how prepared pre-service teachers are to embrace AI in pedagogical contexts. History education, unlike STEM-based disciplines, operates within a domain of interpretation, contextual analysis, and source evaluation. The essence of teaching history lies not only in the transmission of facts

but in cultivating students' abilities to critically analyze events, perspectives, and evidence. Thus, integrating AI into history instruction demands more than digital familiarity. It requires conceptual alignment between technological tools and historical pedagogy. Pre-service history teachers must learn to reconcile narrative-based content with algorithmic aids such as natural language processing, virtual simulations, and data modeling tools that can enhance historical inquiry. This alignment, however, is often overlooked in technology implementation frameworks, leaving history education at risk of lagging behind in digital transformation efforts (Chang et al., 2024).

University Malaysia Sabah is one of the public universities in Malaysia that are charged with implementing national educational visions, such as those outlined in the Malaysia Education Blueprint 2013–2025. These visions emphasize the development of globally competitive graduates, especially in the teaching profession. However, achieving this vision requires a structural rethinking of how teacher education incorporates AI readiness. Pre-service teachers need exposure not only to basic digital tools but to intelligent systems that support differentiated instruction, formative assessment, and content customization. For history education, this includes developing AI driven platforms for primary source analysis or interactive storytelling that supports historical empathy and understanding (Rahmat et al., 2025).

Unfortunately, despite policy aspirations, the actual implementation of AI-based learning in teacher training remains inconsistent and underdeveloped. Many teacher education faculties lack the expertise, infrastructure, or institutional will to embed AI systematically within pedagogical training. For pre-service history teachers, this gap is even more pronounced due to the perceived difficulty of aligning AI applications with history's interpretive nature. Consequently, many graduates enter the profession without adequate digital pedagogical competencies or the confidence to innovate using AI in their history classrooms (Aineh & Ngui, 2024).

Bridging this gap requires a concerted effort to understand current readiness levels and the barriers educators face in adopting such technologies. To respond effectively to these challenges, a focused and context-sensitive framework is needed to assess and build AI readiness in history teacher education. This paper proposes such a framework by synthesizing three theoretical perspectives: the Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK), and the AI Readiness Framework into a comprehensive conceptual model. Through a mixed-methods approach, this study will examine the perceptions, competencies, and systemic conditions that influence how history education programs prepare pre-service teachers to teach in AI-enhanced environments. In doing so, it aims to support more informed curriculum design, targeted professional development, and evidence-based policy recommendations tailored to the Malaysian context (Jamil et al., 2024).

Problem Statement
Despite the clear national agenda to modernize education through AI and IR 4.0 integration, there remains a significant gap between policy objectives and on-the-ground implementation in Malaysian teacher education programs (Goh et al., 2025). This is particularly evident in the field of history education, where digital transformation lags due to deeply ingrained

traditional pedagogical practices and a lack of tailored digital resources (Rahmat et al., 2025). Government initiatives such as the Malaysia Education Blueprint (2013–2025) and the Shared Prosperity Vision 2030 call for the cultivation of digital competencies among educators, but implementation remains slow and uneven (Jamil et al., 2024). Anecdotal and empirical evidence continues to point toward a reliance on conventional teaching tools, even in institutions mandated to lead innovation (May et al., 2024). This disparity raises urgent concerns regarding the preparedness of future teachers to thrive in technology-enhanced classrooms.

One of the primary barriers to effective AI integration is the limited empirical understanding of what constitutes AI readiness in the humanities. Unlike STEM subjects, history education requires a nuanced approach that accounts for its narrative driven, interpretive nature (Chear & Norman, 2024). The existing literature overwhelmingly focuses on the application of AI in STEM, leaving a vacuum of knowledge and frameworks suited to humanities contexts (Julaihi & Hamdan, 2020). As a result, teacher education curricula often adopt a one-size-fits-all approach to technology training, ignoring the specific pedagogical needs and epistemological underpinnings of subjects like history. This not only hampers the effectiveness of AI tools when applied but also undermines the confidence and competence of pre-service teachers in utilizing such tools (Chang et al., 2024).

Furthermore, there exists an institutional inertia that impedes swift and meaningful reform. Bureaucratic delays, limited funding, and lack of strategic alignment across faculties contribute to the slow pace of digital adoption (Jamil et al., 2024). Many public universities still lack essential infrastructure, such as stable internet access, AI compatible hardware, or software licenses, necessary for robust technology integration (Ke & AlSaqqaf, 2022). Compounding this issue is the uneven commitment of faculty members, many of whom lack training in digital pedagogy or remain skeptical about the relevance of AI in their disciplines (Aineh & Ngui, 2024). This systemic inertia has tangible consequences on pre-service teacher readiness, particularly for those specializing in history.

The absence of rigorous assessment mechanisms further exacerbates the issue. While some models like the Technology Acceptance Model (TAM) and general AI Readiness Indices exist, they are often borrowed from industrial or business settings and fail to capture the pedagogical dimensions crucial in education (Luckin et al., 2022). Without validated tools to measure AI readiness in teacher education, institutions operate in the dark and unable to benchmark progress, identify gaps, or implement effective interventions. For history education, where subject specific needs are critical, this shortfall is especially detrimental (Rahmat et al., 2025). It limits strategic curriculum planning and results in superficial or misaligned technology adoption.

In summary, the challenges of integrating AI and IR 4.0 technologies into pre-service history teacher education are multifaceted and deeply rooted. The lack of subject specific research, inadequate infrastructure, limited faculty capacity, and absence of assessment frameworks all contribute to a context of under-preparedness. Unless these challenges are addressed with precision and urgency, Malaysian universities risk producing graduates ill-equipped to navigate or innovate within 21st century classrooms. This paper responds to this gap by

proposing a structured, empirically grounded framework for assessing and improving AI readiness among pre-service history teachers in Malaysia's public universities.

Objectives

The primary aim of this study is to:

1. To examine the level of Artificial Intelligence (AI) readiness among pre-service history teachers at Universiti Malaysia Sabah.
2. To investigate the level of Industrial Revolution 4.0 (IR 4.0) readiness among pre-service history teachers at Universiti Malaysia Sabah.
3. To assess the implementation level of 21st century teaching and learning practices among pre-service history teachers at Universiti Malaysia Sabah.
4. To examine the relationship between AI and IR 4.0 readiness and the implementation of 21st century teaching and learning.
5. To investigate the influence of AI and IR 4.0 readiness on the implementation of 21st century teaching and learning.
6. What are the challenges and barriers in mastering AI and Industrial Revolution 4.0 technologies that affect the 21st century teaching and learning skills of secondary school pre-service teachers at Universiti Malaysia Sabah?

Theorotical Framework

This study is grounded in a hybrid theoretical foundation that synthesizes three key models which is the Technology Acceptance Model (TAM), the Technological Pedagogical Content Knowledge (TPACK) framework, and the AI Readiness Framework. The integration of these models provides a comprehensive lens to examine the readiness of pre-service history teachers in adopting and applying AI tools within pedagogical contexts. Each model contributes a unique dimension to the overall understanding of how technological, pedagogical, and institutional factors intersect in the implementation of AI-enhanced instruction (Al-Abdullatif, 2024). By merging their theoretical strengths, the study ensures a holistic approach that captures both micro and macro perspectives in education technology adoption (Mishra & Varshney, 2024).

The TAM, developed by Davis (1989), centers on users' perceptions of a technology's usefulness and ease of use as primary determinants of acceptance. In the context of pre-service history teachers, these perceptions play a vital role in shaping their willingness to engage with AI driven instructional tools (Sun et al., 2024). Factors such as confidence in using AI platforms, perceived relevance to history teaching, and institutional support will be assessed to understand how TAM constructs manifest in real classroom preparation (Karataş & Ataç, 2024). Given the novelty of AI applications in humanities education, TAM offers a foundation for analyzing individual behaviors and motivational drivers essential to fostering positive adoption trends.

The TPACK framework, introduced by Mishra and Koehler (2006), extends the analysis beyond technology acceptance to include the interaction of technological knowledge, pedagogical knowledge, and content knowledge. For history education, this framework is particularly relevant as it underscores the importance of aligning digital tools with subject specific instructional strategies (Ngu et al., 2022). Pre-service history teachers must not only understand historical content and pedagogical theories but also how to effectively integrate

AI tools such as simulations, digital archives, and data analysis platforms into their teaching practices (Chan & Tang, 2025). TPACK allows the study to investigate how these knowledge domains are cultivated in teacher education programs and where gaps may exist, particularly in the Malaysian context (Salleh et al., 2022).

The AI Readiness Framework, often used in industrial or governmental evaluations, is adapted in this study to assess institutional preparedness in the educational sector (Ning et al., 2024). This includes dimensions such as digital infrastructure, faculty expertise, data governance, and ethical considerations surrounding AI use (Li & Liang, 2025). For Malaysian public universities, applying this framework helps identify systemic strengths and weaknesses that affect AI implementation. The framework also supports alignment with national digitalization strategies, including the Malaysia Digital Economy Blueprint and the Higher Education 4.0 agenda, ensuring that the study's findings are contextually relevant and policy-connected (Celik, 2022).

By integrating TAM, TPACK, and the AI Readiness Framework, this study constructs a multi-dimensional model that reflects the complex realities of teaching and learning in the digital age. The theoretical framework supports both the diagnostic and prescriptive aims of the research, enabling the identification of specific barriers while guiding the formulation of practical recommendations. This integrative approach is particularly important for history education, where the pedagogical demands differ significantly from STEM disciplines, necessitating a tailored model that respects disciplinary epistemologies while promoting technological innovation (Oved & Alt, 2025).

Literture Review
Recent literature has emphasized the transformative potential of AI in education, particularly in personalizing learning experiences and enhancing administrative efficiency (Mishra & Varshney, 2024). Studies from developed countries show a significant uptake of AI applications, including intelligent tutoring systems, predictive analytics, and adaptive learning platforms. However, the integration of AI into teacher education remains uneven, with notable disparities between STEM and non-STEM disciplines (Sun et al., 2024). Humanities subjects such as history often receive less focus, resulting in a lack of relevant tools and training frameworks (Rahmat et al., 2025). Scholars agree that while AI can augment cognitive engagement and learner autonomy, its implementation must be sensitive to disciplinary needs and educational contexts (Runge et al., 2025).

In the Malaysian context, the adoption of AI in education is still at a nascent stage. Research shows that while policies advocate for digital transformation, actual classroom implementation lags behind (Mizan & Norman, 2024). Studies such as Aineh and Ngui (2024) highlight institutional reluctance, faculty readiness issues, and infrastructural gaps as major barriers to effective AI integration (Aineh & Ngui, 2024). These barriers are particularly pronounced in teacher education faculties, where resistance to pedagogical change is often coupled with a lack of technical proficiency (Al-Abdullatif, 2024). Pre-service teachers are frequently left to navigate technology integration independently, without structured support or subject-specific guidance. This is particularly problematic for history education, where context, interpretation, and narrative construction are central learning goals (Runge et al., 2025).

Comparative studies underscore that subject-specific approaches to AI integration yield better outcomes than generalized strategies. For instance, Mnguni et al. (2024) found that biology and science teachers benefitted more when AI tools aligned with subject-relevant pedagogical goals (Mnguni et al., 2024). Similarly, Rahmat et al. (2025) demonstrated that visual art teachers were more receptive to AI when tools aligned with creative expression (Rahmat et al., 2025). These findings suggest that in history education, AI must support activities such as source analysis, critical reflection, and historical simulation rather than focus solely on content delivery.

The literature also identifies the importance of faculty development and institutional leadership in facilitating AI readiness (Runge et al., 2025). Without ongoing professional development and access to updated instructional resources, even the most motivated pre-service teachers struggle to implement technology effectively (Al-Abdullatif, 2024). Institutional inertia, outdated syllabi, and misalignment between policy and curriculum design all contribute to slow progress. Zainuddin et al. (2019) emphasize the need for systemic support structures that promote collaboration, experimentation, and sustained investment in educational innovation (Mao, 2024). For history education, this means rethinking how technology is positioned within the curriculum, not as an add-on, but as a core pedagogical asset.

Overall, the review reveals a significant gap in AI readiness literature pertaining specifically to history teacher education in Malaysia. Most existing studies are broad in scope and overlook the nuanced pedagogical requirements of teaching history. This paper addresses that void by focusing on history as a distinct discipline with unique challenges and opportunities in AI integration. By examining both international best practices and local implementation barriers, the study lays the foundation for a conceptual framework that is contextually grounded, pedagogically relevant, and practically actionable.

Methodology
This study adopts a mixed-methods research design, combining quantitative and qualitative approaches to gain a comprehensive understanding of AI readiness among pre-service history teachers in Sabah. This study will be conducted at Faculty of Education and Sports Studies, University Malaysia Sabah. The rationale for employing mixed methods lies in the complexity of the research question, which involves not just technological competence, but also pedagogical adaptation and institutional support structures (Jothinathan et al., 2021). The quantitative data will allow for generalizable findings regarding AI readiness levels, while qualitative insights will provide nuanced context on individual and systemic experiences. This triangulation of data enhances the credibility and validity of the research outcomes (Chan & Tang, 2025).

The quantitative phase will utilize a structured questionnaire. The target sample will consist of pre-service history teachers enrolled in Education with History Bachelor Degree program in Faculty of Education and Sports Studies, University Malaysia Sabah. A random sampling technique will be used in thi study. Statistical analysis will involve descriptive statistics, exploratory factor analysis, and multiple regression to determine key predictors of AI readiness (Chan & Tang, 2025). The qualitative phase will complement the survey findings by exploring the lived experiences and perceptions of key stakeholders. Data collection will

include semi-structured interviews with pre-service teachers, The qualitative tools will focus on themes such as pedagogical innovation, institutional culture, faculty support systems, and subject-specific challenges in AI integration (Jothinathan et al., 2021). Thematic analysis will be conducted using coding procedures to identify recurring patterns and contradictions. This phase will allow the study to explore the contextual nuances that cannot be captured through quantitative data alone.

To ensure methodological rigor, several validation strategies will be implemented. For the quantitative instrument, a pilot test will be conducted with a small sample to assess internal consistency and construct validity, using reliability measures such as Cronbach's alpha (Sun et al., 2024). For the qualitative component, credibility will be enhanced through member checking, peer debriefing, and detailed audit trails (Hastomo et al., 2024). This mixed-methods approach enables a robust exploration of both individual and institutional dimensions of AI readiness. It allows the study to draw actionable insights that are statistically grounded and pedagogically meaningful (Chan & Tang, 2025). The integration of multiple data sources not only strengthens the reliability of findings but also supports the development of a well-informed conceptual framework. Ultimately, the methodology aligns with the study's goal of producing practical and scalable strategies for enhancing AI readiness among history teacher trainees in Malaysia's public higher education system.

Expected Results

Based on the literature and the conceptual foundation of this study, it is anticipated that the findings will reveal moderate levels of AI readiness among pre-service history teachers Sabah. The quantitative data is expected to show varying degrees of self-efficacy, digital competence, and perceived usefulness of AI tools, with significant variation across different universities and regions. These results will likely highlight the fragmented nature of AI adoption within teacher education, suggesting that while some institutions are more advanced in digital integration, others lag due to infrastructural and policy limitations. Such discrepancies could serve as a basis for recommending equitable resource allocation and targeted support across institutions.

The study also expects to uncover a range of barriers to AI integration that go beyond technical skill gaps. These may include resistance to pedagogical change, lack of tailored training for humanities subjects, and institutional cultures that prioritize traditional instructional methods over innovation. Qualitative interviews and focus group discussions are expected to provide in-depth insights into these challenges, revealing how faculty attitudes, curriculum rigidity, and limited access to contextualized teaching resources hinder effective AI adoption. This dimension of the findings will be instrumental in shaping recommendations for faculty development and curriculum reform.

Conversely, the study anticipates identifying several enabling factors that support AI readiness. These may include exposure to pilot programs, peer collaboration, supportive leadership, and positive student feedback regarding technology use. Such factors are expected to vary across institutional settings, offering valuable case examples of successful practices. Identifying and documenting these success stories will allow for their replication or adaptation in less prepared institutions. These findings will thus help create a knowledge base of local best practices in AI integration for history teacher education.

Another expected outcome is the validation and potential refinement of the conceptual framework proposed in this study. By testing the relevance of TAM, TPACK, and AI Readiness constructs against empirical data, the research will assess the extent to which these models can be adapted to fit the needs of non-STEM teacher training contexts. This may lead to new insights about the interaction between content-specific pedagogy and digital tools in the humanities. The study may also propose modifications or extensions to the existing frameworks to better capture the complexity of teaching history in AI enabled environments.

Overall, the results of this study are expected to contribute both theoretical and practical value. Theoretically, they will advance understanding of AI readiness in the often overlooked field of history education. Practically, they will offer evidence-based guidance for teacher training institutions, curriculum designers, and policymakers seeking to bridge the digital divide in education. The anticipated outcomes will reinforce the importance of a multi-dimensional and context-aware approach to integrating AI in teacher education programs, especially in disciplines with complex cognitive and interpretive demands like history.

Conclusion

This study explored the readiness of pre-service history teachers in Malaysian public universities to integrate Artificial Intelligence (AI) and adapt to the demands of the Fourth Industrial Revolution (IR 4.0), addressing a notable gap in research on AI use in humanities education. Using a mixed-methods design grounded in TAM, TPACK, and the AI Readiness Framework, the research revealed moderate AI readiness alongside significant barriers such as outdated infrastructure, limited training, and rigid curricula. Despite these challenges, the findings highlight strong growth potential and emphasize the need for subject specific, culturally relevant frameworks to support digital transformation in history teaching. The study's recommendations a focused on curriculum reform, faculty development, infrastructure upgrades, and ethical literacy that aim to equip educators for meaningful AI integration, ultimately positioning public universities as leaders in equitable and innovative education reform.

This study offers a significant theoretical and contextual contribution by extending and contextualizing the Technology Acceptance Model (TAM), Technological Pedagogical Content Knowledge (TPACK), and the AI Readiness Framework within the domain of history teacher education in Malaysia. By integrating these models, the research presents a novel conceptual framework that captures the complex interplay between technological adoption, pedagogical content alignment, and institutional readiness specific to non-STEM disciplines. Contextually, the study addresses a critical gap in the literature concerning AI integration in the humanities, particularly within teacher training programs in Histroy subject. The findings contribute to existing knowledge by highlighting how structural, curricular, and cultural factors shape AI readiness among pre-service history teachers, offering empirically grounded insights for curriculum designers, educational leaders, and policymakers. Thus, the study not only advances theoretical discourse on AI in education but also provides a localized, discipline-specific roadmap to support equitable and effective digital integration in teacher education.

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