AI-Enhanced Teaching Tools in Higher Education: A Literature and Requirements Analysis

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Abstract

This paper presents a comprehensive literature and requirements analysis of AI-enhanced teaching tools in higher education. Through systematic review of recent publications, we examine current AI applications in university teaching including chatbots, virtual teaching assistants, intelligent tutoring systems, and adaptive learning platforms. While these tools are increasingly deployed, the literature reveals a critical gap: implementation requirements remain largely unspecified. We address this by deriving essential requirements across technological, ethical, organizational, and pedagogical dimensions, alongside necessary metadata standards. Our analysis demonstrates that successful AI adoption demands holistic institutional transformation encompassing governance frameworks, professional development, and standardized data schemas, not merely technological deployment. This study provides universities with an evidence-based implementation roadmap while establishing foundations for future empirical research on AI-enhanced teaching effectiveness.

Keywords: *AI-Enhanced Teaching Tools, Chatbots, Virtual Teaching Assistants, Intelligent Tutoring Systems, Implementation Requirements, Educational Metadata*

1. Introduction

The integration of artificial intelligence (AI) in higher education institutions has accelerated rapidly and gained considerable importance, promising to transform traditional pedagogical approaches whose limitations are particularly evident in providing personalized feedback—through adaptive, individualized learning experiences [1]. However, successful implementation requires meeting various prerequisites. Many universities currently lack standardized guidelines, complicating practical deployment. An analysis of US universities reveals that generative

AI use remains inconsistently regulated, leaving instructors to navigate substantial adaptation challenges independently [2].

Current literature extensively documents various AI applications in educational settings yet fails to systematically address the prerequisites for effective implementation. This gap is particularly problematic as institutions struggle with inconsistent adoption strategies, inadequate infrastructure, and unclear governance frameworks—issues that risk undermining the transformative potential of these technologies.

This paper addresses this gap through a systematic literature and requirements analysis. The central research question to be answered in this academic paper is:

What is required to successfully develop AI-supported teaching systems and thus support and improve university teaching?

Furthermore, the following sub-question is to be answered:

What metadata is required to enable the use of AI-supported teaching systems?

Through comprehensive analysis of recent literature (2023-2025) using Webster & Watson's systematic approach [3], we identify and categorize implementation requirements across technological, ethical, organizational, and pedagogical dimensions. Furthermore, we derive essential metadata specifications necessary for AI tool functionality. This analysis provides universities with an evidence-based framework for AI adoption while highlighting critical areas requiring further empirical investigation.

2. Background

The theoretical background forms the basis of this research work and serve to define relevant terms that are essential for understanding the research project.

2.1 Artificial Intelligence

Artificial Intelligence represents a transformative technology characterized by systems capable of interpreting data, learning from patterns, and adapting behavior autonomously [4]. Recent advances in AI, particularly through large language models (LLMs) and deep learning architectures, have expanded possibilities for educational applications beyond traditional rule-based systems. These technologies enable machines to process natural language, recognize complex patterns, and generate contextually appropriate responses which are capabilities particularly relevant for educational interactions [5].

2.2 AI-Enhanced Teaching

The emergence of generative AI and LLMs marks a paradigm shift in educational technology. Unlike earlier systems limited to predefined responses, modern AI can engage in sophisticated dialogue, create original content, and provide nuanced feedback: approaching human-like tutoring capabilities while operating at unprecedented scale. AI-enhanced teaching encompasses the integration of artificial intelligence technologies to augment, support, and transform educational processes in higher education. This approach extends beyond digitization to fundamentally reimagine how teaching and learning occur [6].

Central to this transformation is AI's potential to address Bloom's "2 sigma problem", the finding that one-on-one tutoring produces learning outcomes two standard deviations better than conventional classroom instruction [7]. While individual tutoring remains economically unfeasible at scale, AI-enhanced tools offer a promising solution by providing personalized, mastery-based learning experiences to multiple students simultaneously.

The promise of AI-enhanced teaching lies in democratizing high-quality, personalized education previously available only through individual tutoring. By providing each student with responsive, adaptive support, these technologies address persistent challenges in higher education while creating more engaging learning experiences [8]. However, realizing this potential requires careful consideration of implementation requirements: a gap this research addresses through systematic analysis.

3. Methodology

The systematic literature review followed Webster & Watson's methodology [3], searching seven major databases (IEEE Xplore, AIS Electronic Library, ACM Digital Library, ArXiv, Google Scholar, SpringerLink, and ScienceDirect). Search terms included combinations of "artificial intelligence," "AI-enhanced," "teaching tools," "higher education," "university," "implementation," and "requirements" with Boolean operators. Publications were limited to 2023 onwards to capture current AI developments. Forward and backward searches identified additional relevant sources. After removing duplicates and screening abstracts for relevance, 16 articles met the inclusion criteria. Through this process, we identified both the current landscape of AI-enhanced teaching tools and the requirements necessary for their successful implementation.

4. Results

The concept matrix analysis reveals the current landscape of AI-enhanced teaching tools and their implementation requirements in higher education (see Table 1). Column characteristics were systematically derived from the analyzed literature, with crosses marking when sources addressed specific characteristics. The analysis identified four primary categories of AI-enhanced tools, and four essential requirement dimensions as described below.

Sources	Tool Category				Requirement Category			
	CB	VTA	ITS	ALS	TR	ER	OR	PR
[10] – Alawneh et al., 2024				X				
[11] – Conklin et al., 2024	X							
[12] – Dhasarathan et al., 2025	X	X	X	X				
[13] – Kostikova et al., 2024	X							
[14] – Liu et al., 2024	X							
[9] – Maiti & Goel, 2024		X						
[15] – Maphalala & Ajani, 2025					X	X	X	X
[16] – Meron & Araci, 2023	X							
[17] – Nagy et al., 2023	X							
[5] – Pisica et al., 2023					X	X		
[8] – Rouabhia, 2024	X							
[18] – Shchaveleva et al., 2024	X	X	X	X				
[19] – Thangasamy et al., 2025		X	X	X	X	X		X
[20] – Thiyagarajan & Vijayalakshmi, 2025		X						
[21] – Tran et al., 2024	X							
[22] – Zhou, 2024			X					
Number in total	**9**	**5**	**4**	**4**	**3**	**3**	**1**	**2**

Table 1 Concept matrix [3] showing the distribution of tool and requirement categories among the 16 articles identified.

4.1 AI-Enhanced Teaching Tools

AI-enhanced teaching tools represent a category of educational technologies that leverage artificial intelligence to augment traditional pedagogical practices. These tools employ various AI methods including machine learning, natural language processing, and predictive analytics to create dynamic, responsive learning environments [6].

Unlike conventional educational software, AI-enhanced tools adapt to individual learners, analyze learning patterns in real-time, and provide personalized interventions [9]. The primary categories of AI-enhanced teaching tools identified in educational settings include:

Chatbots and Conversational Agents (CB)

Chatbots emerged as the most prevalent tool category with nine occurrences, indicating exceptional prominence in current research. These AI-based systems interact with users through natural dialogue, simulating human-like conversations while generating content autonomously [10, 11]. In educational contexts, chatbots serve multiple functions: motivating task completion, personalizing learning experiences, conducting assessments, and generating educational content [11].

They facilitate human-like dialogues, deliver individualized language exercises, and provide immediate feedback [8, 11]. Instructors leverage chatbots for creating lesson plans, quizzes, and instructional materials [8, 21]. Notable implementations include ChatGPT as a "knowledge colleague" supporting idea generation and text quality improvement [21], and as a collaborative partner in course creation [17].

Virtual Teaching Assistants (VTAs)

With five occurrences, VTAs demonstrate significant relevance in the analyzed literature. These AI-powered conversational assistants answer questions using instructor-provided course materials and engage in content-based dialogues [9]. VTAs support diverse cognitive demands, encouraging students to engage in sophisticated thinking processes and promoting active classroom participation [9, 20]. They provide comprehensive didactic support through definitions, examples, comparisons, and content summaries, substantially reducing instructor workload [9]. A practical implementation example includes a specialized VTA for Java programming instruction, enabling instructors to delegate real-time coding feedback [20].

Intelligent Tutoring Systems (ITS)

Four publications addressed ITS, highlighting their role as AI-controlled tools that emulate human tutors and moderators [22]. These systems enable targeted learning process monitoring while automatically providing personalized feedback and content based on individual proficiency levels [19]. Through machine learning algorithms, ITS analyze student strengths and weaknesses, generating data-driven insights for targeted instructional support [19]. Additionally, ITS facilitate collaborative learning by enabling instructors to form groups based on complementary student abilities [19]. The Cognitive Tutor for mathematics exemplifies successful ITS implementation [19].

Adaptive Learning Systems (ALS)

Also appearing in four sources, ALS represent transformative solutions that integrate AI to create flexible, responsive curricula. These systems enable dynamic adaptation of content, pacing, and assessment methods according to individual learning patterns [10]. Based on unique learning trajectories, instructors use ALS to provide differentiated opportunities tailored to learner needs and preferences [19]. ALS foster engaging, effective learning experiences while enabling real-time progress monitoring for timely interventions and customized support [10]. Implementation examples include collaborative filtering algorithms for peer-based resource recommendations [10]. EdX's personalized learning paths with real-time feedback [19] and ALOHA (Adaptive Learning with Online Hints and Assessments) providing adaptive instructional formats [10].

These tools share common objectives: enhancing learning personalization, automating routine instructional tasks, providing data-driven insights, and enabling scalable educational support. Their implementation promises to address persistent challenges in higher education, particularly the provision of individualized feedback and support at scale [1].

4.2 Requirements for Successful Implementation

The analysis of the identified literature reveals that successful AI-enhanced tool implementation demands attention to multiple dimensions beyond technical deployment. Following Maphalala and Ajani [15], requirements span technological, ethical, organizational, and pedagogical domains.

Technological Requirements

Dhasarathan et al. emphasize that successful implementation requires seamless integration of hardware, software, and network components [12]. Essential infrastructure includes high-capacity storage and high-speed internet connectivity. This position receives support from Zhou [22] and Thangasamy et al. [19], who confirm that robust technological infrastructure forms the foundation for implementation success. Maphalala and Ajani extend these requirements to include support systems, interoperability, and scalability [15]. Effective data management emerges as another crucial requirement, encompassing the complete data lifecycle from collection through storage to analysis, enabling personalized learning and predictive analytics [19]. Therefore, scalable core infrastructure with powerful computing and network resources represents a fundamental technological prerequisite. Additionally, interoperability through open interfaces ensures seamless integration between AI-enhanced tools and existing learning management systems.

Ethical Requirements

Beyond technical considerations, Maphalala and Ajani argue that institutions must ensure accessibility and inclusion for all users [15]. Both these authors and Rouabhia [8] warn against algorithmic bias, as AI systems may contain unintentional biases leading to discriminatory outcomes in performance assessments or admissions. Consequently, institutions must implement continuous algorithm analysis and bias mitigation procedures to prevent discrimination.

Academic integrity concerns feature prominently in the literature, with Tran et al. [21] and Meron and Araci [16] highlighting plagiarism risks. This necessitates maintaining academic integrity through binding guidelines and examination formats incorporating originality verification. Data privacy represents another critical consideration, as Pisica et al. [5] and Shchaveleva et al. [18] note extensive student data collection and analysis. Strict policies and governance frameworks must ensure trustworthy, ethical implementation.

Organizational Requirements

Successful implementation also depends on organizational readiness. Pisica et al. attribute implementation costs to lacking strategic vision, arguing that institutions often misunderstand the implications and processes of AI-enhanced tool deployment [5]. Given the substantial computing and network resources required [12], institutions must develop clear strategic visions with integrated financing plans.

Zhou emphasizes instructor involvement in design and implementation processes to ensure tools meet their needs and preferences, thereby promoting acceptance [22]. Both Dhasarathan [12] and Maphalala and Ajani [15] stress the importance of continuous professional development through training programs and workshops for smooth classroom integration.

Pedagogical Requirements

Tran et al. identify connections between technological expertise and pedagogical competence, suggesting that instructor technological proficiency significantly influences digital transformation success [21]. Zhou [22] reinforces this, emphasizing continuous AI-related knowledge expansion for successful implementation. From the student perspective, Dhasarathan et al. argue that implementation success depends heavily on student engagement, requiring tools tailored to promote motivation and learning achievement [12]. Therefore, AI-enhanced tools must be implemented interactively with learner-centered approaches to sustain long-term motivation and success.

4.3 Metadata for AI-Enhanced Teaching

Effective AI implementation in university teaching requires not only the use of AI tools but also the establishment of clear, standardized, and machine-readable metadata. In this context, metadata refers to structured descriptive information about courses, learners, and instructional processes that enables AI systems to retrieve, interpret, and generate relevant outputs in a pedagogically aligned manner. The literature identifies several distinct categories of metadata that are essential for the functionality and effectiveness of AI-enhanced tools.

Educational Metadata: Rouabhia employs ChatGPT to generate course materials based on structured course descriptors, including the course name, program, academic level, target audience, credit points, course content, and learning objectives [8]. Such metadata ensures that AI-generated materials are aligned with curricular requirements and appropriate for the intended audience. Similarly, Thiyagarajan & Vijayalakshmi describe a Virtual Teaching

Assistant that requires teacher-specified subject areas and task parameters to deliver relevant support [20].

Student Data: Alawneh et al. design adaptive learning systems that use user profiles, historical performance records, and identified learning styles, which are analyzed through machine learning algorithms to tailor content delivery [10]. These profiles evolve over time through integrated feedback mechanisms, which refine both the student data and the quality of AI outputs, enabling personalized learning pathways.

Instructional Components: Thiyagarajan & Vijayalakshmi present VTAs requiring teacher-specified subject areas and task parameters [20]. Liu et al. describe chatbots using system prompts, course rules, guidelines, and conversation history to generate pedagogically appropriate responses [14].

The metadata identified encompasses:

- Educational data (course details, objectives, program information)
- Student profiles (performance metrics, interaction patterns, learning styles)
- Formatted assignments and evaluation rubrics
- Feedback data for validation and improvement
- Persona prompts assigning specific roles
- Context-dependent prompts for targeted outputs

Given these requirements, institutions should develop and maintain standardized metadata schemas that incorporate all relevant elements in a consistent, interoperable format. Such schemas should ensure completeness, machine readability, and accessibility for AI systems, thereby facilitating automation, personalization, and adherence to pedagogical goals.

4.4 Research Gap

The concept matrix reveals a significant imbalance: while extensive research documents AI-enhanced tool applications, minimal attention addresses implementation prerequisites. Studies frequently describe tool usage without specifying necessary conditions for success. For instance, Kostikova et al. detail ChatGPT's application in legal English course development without articulating implementation requirements [13]. Similarly, Conklin et al. examine ChatGPT for course creation without identifying specific prerequisites [11]. Only Thangasamy et al. comprehensively address technological, ethical, and pedagogical considerations [19].

This gap proves critical—mere tool deployment cannot guarantee successful implementation. Without comprehensive understanding of prerequisites, institutions risk implementation failure. The following section addresses this gap by systematically deriving requirements from the analyzed literature.

5. Conclusion

The systematic analysis of AI-enhanced teaching tools reveals both promising applications and critical implementation gaps in higher education. While chatbots (CB), VTAs, ITS, and ALS demonstrate diverse educational applications, the literature exhibits a concerning technology-centric bias. Essential prerequisites (ethical frameworks, governance structures, professional development, and metadata standards) receive minimal attention despite their fundamental importance for sustainable adoption.

Our findings show a strong disconnect between technological possibilities and implementation realities. The prevalence of chatbot studies suggests enthusiasm for scalable solutions, yet the path from pilot projects to integrated, ethically responsible systems remains underexplored. This gap is particularly problematic as universities risk implementation failure without comprehensive understanding of multidimensional requirements.

The study makes three key contributions: (1) systematic identification of AI tool categories currently deployed in higher education, (2) a comprehensive requirements framework spanning technological, ethical, organizational, and pedagogical dimensions, and (3) specification of metadata standards essential for AI functionality. This framework transforms AI implementation from isolated technological deployment into holistic institutional transformation requiring strategic planning, continuous professional development, and systematic evaluation.

Several limitations should be noted. The temporal restriction to recent publications may exclude established insights, while the matrix structure potentially oversimplifies complex interdependencies. Most critically, empirical validation of the derived requirements remains pending.

Moving forward, universities must recognize that successful AI integration demands more than tool selection: it requires fundamental institutional adaptation. Critical questions persist regarding institutional readiness, concrete impacts on learning and assessment, and the availability of standardized metadata infrastructures. Future research should pursue empirical validation through case studies and stakeholder interviews, with particular attention to organizational and ethical dimensions crucial for sustainable adoption.

This work contributes to AI in education research by revealing implementation challenges and offering a practical, evidence-based guide for universities adopting these technologies. Only by addressing all requirement dimensions (technological, ethical, organizational, and pedagogical) can AI-enhanced teaching tools achieve their potential to deliver high-quality, personalized education to all students.

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