Revolutionizing Teachers' Professional Development: The Critical Role of AI-Based Tools from Initial Training to Lifelong Learning—A Case Study

Mohammed Lamrabet*, Hamza Fakhar, Noureddine Echantoufi, Khalid EL Khattabi, and Lotfi Ajana

Center for Doctoral Studies: Sciences, Technologies, and Medical Sciences, Laboratory of Computer and Interdisciplinary Physics (LIPI), Ecole Normale Superieure (ENS), Sidi Mohamed Ben Abdellah University, Fez, Morocco

Email: mohammed.lamrabet@usmba.ac.ma (M.L.); hamza.fakhar@usmba.ac.ma (H.F.); noureddine.echantoufi@usmba.ac.ma (N.E.); khalid.elkhattabi@usmba.ac.ma (K.E.K.); lotaja@yahoo.fr (L.A.)

*Corresponding author

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***Abstract*—The rapid integration of Artificial Intelligence (AI) across various sectors, particularly in education, is gaining increasing scholarly attention. In the Moroccan context, AI integration in education faces significant challenges, including limited infrastructure, insufficient teacher training, and varying levels of familiarity with AI technologies. These barriers highlight the need to investigate how external knowledge-related factors influence perceptions of integrating AI-based tools among future and experienced teachers. This study examines these perceptions and the necessity of integrating AI-based tools from the initial training of Moroccan teachers to their lifelong learning. Employing a quantitative, descriptive, and exploratory design, data were collected through a validated questionnaire administered to two distinct groups: 244 future teachers in their third year of training at the Higher Normal School (ENS) in Fez, and 238 experienced teachers working in public schools across the Fez-Meknes region. The experienced teachers were recruited using a snowball sampling technique. The collected data were analyzed using robust statistical methods. The results demonstrate a significant positive correlation between knowledge of AI-based tools and perceptions of their importance among both future and experienced teachers. Additionally, interest in and mastery of emerging technologies—part of the Technological Proficiency Factor—were identified as critical determinants of positive perceptions. Despite existing contextual barriers, there was a strong consensus on the importance of integrating AI-based tools within teacher training programs, regardless of years of professional experience. This study contributes to the limited body of research on both the opportunities and challenges of AI integration within the Moroccan educational context and underscores the necessity of incorporating AI competencies into initial teacher training curricula to shape the future of teacher education.**

***Keywords*—Artificial Intelligence (AI), AI-based tools, future teachers, experienced teachers, Integration, initial training, lifelong learning**

I. Introduction

Artificial Intelligence (AI) has emerged as a transformative technology since the mid-20th century, with Alan Turing's 1950 introduction of the Turing Test marking a significant milestone. The 1956 Dartmouth Workshop formally established AI as a field focused on creating machines that emulate human learning and problem-solving [1–3].

Key subfields of AI include Machine Learning (ML), Deep Learning (DL), Natural Language Processing (NLP), computer vision, and generative AI, which produce original content from extensive datasets. AI is classified into narrow AI, designed for specific tasks, and Artificial General Intelligence (AGI), which aims to replicate human-like intelligence [4].

In education, AI has revolutionized teaching and learning processes [5], offering innovative solutions that enhance both personalized instruction and administrative efficiency [6]. For example, ML algorithms enable tailored educational experiences by analyzing data and adapting content to individual needs [7]. AI's integration into education can be seen in three key areas: Learner-Facing AI, such as Intelligent Tutoring Systems; Teacher-Facing AI, which automates tasks like grading and progress tracking; and System-Facing AI, which supports institutional management through data-driven insights. This broad range of AI applications has been shown to improve both educational outcomes and operational efficiency [8, 9].

The responsible integration of AI into education requires adhering to legal, regulatory, and ethical standards to ensure legitimacy and maximize its transformative potential in personalized learning and academic achievement [10]. Recent research underscores the significant impact of AI-based tools across various educational levels, demonstrating their potential to enhance teaching methodologies, streamline administrative tasks, and personalize learning experiences [11–13]. The Beijing Consensus on AI and education advocates for coherent, system-wide strategies aligned with educational policies, within a lifelong learning perspective [14].

Despite these advances, integrating AI into education is not without challenges. Factors such as AI-related anxiety, perceived usefulness, readiness, and teacher attitudes significantly influence educators' intentions to adopt AI technologies in their practices. Research reveals a critical need for comprehensive training programs to address these issues for both future and experienced educators [15]. Furthermore, effective integration necessitates critical reflection on the legal, ethical, pedagogical, psychological, and sociological implications of AI use in educational settings [16].

While advancements in AI offer substantial benefits for the professional development of educators in initial training [17], there remains a notable gap in the Moroccan educational context, where the integration of AI remains nascent. Limited access to AI technologies and a lack of incorporation into teacher training curricula hinder effective implementation. To date, no scientific studies have examined perceptions of

AI integration among future teachers in Morocco, especially regarding lifelong learning. Addressing these gaps is crucial for building a comprehensive understanding and ensuring effective AI usage in the educational landscape.

Challenges persist, including AI's limitations in handling complex subject matter, the need for effective integration, insufficient access to AI tools, lack of curriculum integration in teacher training programs, ethical concerns regarding data privacy and algorithmic bias. In addition, many educators express a lack of understanding and training in AI technologies, hindering effective implementation [18, 19].

To fully harness the potential of AI in education and address the identified gaps, it is imperative for educators and policymakers to collaborate in overcoming these challenges while maintaining ethical standards. Ongoing exploration and innovation in AI applications are essential to optimize its benefits within the educational landscape. Additionally, leaders of initial teacher training programs, particularly within Higher Normal School (ENS), must develop and implement a comprehensive strategy for the integration of AI-based tools into the curriculum. This will ensure that future teachers are adequately equipped with the necessary skills and knowledge to effectively utilize these technologies.

Given this context, the present study seeks to investigate the factors influencing perceptions regarding the necessity of integrating AI-based tools from the initial training of future Moroccan teachers to lifelong learning. Employing a case study approach focused on two distinct groups: future teachers in their third year of training at the ENS of Fez, and experienced teachers working in public schools across the Fez-Meknes region, the research utilizes a quantitative, descriptive, and exploratory methodology. Data collection was conducted using a paper-based questionnaire administered to a simple random sample of future teachers enrolled at ENS of Fes. For experienced teachers, data were collected through an online questionnaire distributed via Google Forms. The recruitment of experienced teachers was facilitated through a snowball sampling technique, a non-probability method that involved utilizing personal networks and professional connections to identify initial participants, who subsequently referred additional experienced teachers to participate in the survey. These participants represent various specializations (primary, scientific, and literary).

Robust statistical methods were employed to analyze the data, tailored to the study's objectives and the nature of the variables. These included:

- Correlation Analysis to evaluate inter-item relationships and ensure construct cohesion.
- Exploratory Factor Analysis (EFA) to uncover latent structures and reduce data dimensionality.
- Confirmatory Factor Analysis (CFA) to validate the factor structure and assess the construct validity of the measures.
- Frequency Analysis to describe the distribution of participant responses and identify key trends.
- Contingency table combined with the Chi-square test to examine relationships between categorical variables, with measures of association (Cramer's V and Gamma) providing additional insights.
- Ordinal Logistic Regression to investigate the influence of predictor variables on the perceived necessity to integrate AI-based tools in initial teacher training.

II. Literature Review

A. Artificial Intelligence: Evolution, Key Concepts, and Current Developments

AI is a rapidly evolving technology that continues to transform traditional practices and redefines paradigms across all sectors. While early visions of intelligent automatons date back to ancient civilizations, significant advancements in AI research began in the mid-20th century. A landmark moment came in 1950 when Alan Turing introduced the Turing Test, the foundation for assessing machine intelligence, laying the groundwork for AI's core principles [20, 21]. Turing's seminal work [3], "Computing Machinery and Intelligence," is considered a cornerstone of AI, even before the term "Artificial Intelligence" was coined by John McCarthy in 1956 [6, 22]. Turing's vision included developing computer programs like chess engines that demonstrated intelligent reasoning, with games serving as an initial tested for AI as suggested by Claude Shannon [2, 23].

The 1956 Dartmouth Workshop, organized by John McCarthy and Marvin Minsky, is widely regarded as the birth of AI as a field, aiming to create machines that simulate human learning, cognition, language use, problem-solving, and autonomous operation [24–26]. Over the years, various definitions of AI have emerged. For instance, Alan Turing highlighted AI's ability to communicate, reason, and adapt to new challenges [3], while Wilson and Keil later introduced the Cognitive Modeling definition, which focuses on AI's capacity to think and act like humans. As AI continues to advance, its ability to match human problem-solving capabilities increases, enabling more profound applications [21, 22, 24].

AI remains inherently multidisciplinary, employing diverse techniques like rule-based systems and neural networks to replicate human-like skills in problem-solving, learning, and autonomous decision-making [5, 22, 27, 28].

Recent advancements in AI have been primarily fueled by ML, which develops adaptive algorithms that learn from data and improve without explicit programming. These models process large datasets, identify patterns, and make highly accurate predictions, often surpassing human capabilities. In particular, the emergence of DL, a specialized ML area utilizing multi-layered neural network, has driven innovations in various technologies. This shift toward adaptive AI has broadened its applications across numerous sectors, solidifying its role as a key driver of modern technological innovation [22, 29–32].

AI is composed of several key subfields, each of which contributes to its diverse range of applications [4, 7, 29–31, 33, 34]:

- **Machine Learning (ML)** focuses on developing algorithms that enable computers to autonomously learn from data, supporting tasks such as data analysis, pattern recognition, and numerous practical applications.
- **Deep Learning**, a subset of ML, utilizes neural networks with many layers to analyze complex patterns in large datasets, excelling in image recognition and speech processing, NLP, and autonomous vehicles.

- **Big data** provides the vast amount of information required to train these AI models, enabling predictions that are more accurate and deeper insights.
- **Natural Language Processing (NLP)** facilitates seamless interaction between computers and human languages, allowing machines to understand, generate, and respond to human text and speech, which is crucial for applications like language translation, sentiment analysis, and Chatbots.
- **Computer Vision** equips machines with the ability to interpret and analyze visual data from the world, such as images and videos, allowing them to make informed decisions based on visual inputs.
- **Robotics integrates AI** with mechanical systems, creating intelligent robots capable of performing complex tasks and interacting within human environments, often following social norms.
- **Generative AI** is dedicated to producing new and original content, such as text, images, and music, using advanced AI models that learn from extensive datasets rather than being explicitly programmed.
- **Cloud Computing** plays a critical role by providing scalable and flexible access to computing resources over the internet, which accelerates AI development and deployment processes.
- **Blockchain**, a secure and decentralized ledger technology, enhances the transparency and reliability of digital transactions, ensuring tamper-resistant record keeping across industries.

Together, these subfields drive the ongoing advancement of AI, reinforcing its pervasive influence across multiple sectors and domains.

AI can be categorized into two primary types: Narrow AI and General AI. Narrow AI, also known as Weak AI, is designed for specific tasks like language translation, virtual assistance, or strategic games such as chess. It excels within its specialized area but lacks broader cognitive abilities, preventing it from adapting to tasks outside its designated functions.

General AI, or AGI, remains theoretical. It aims to replicate human-like intelligence, with the ability to perform a wide range of tasks involving reasoning, learning, and emotional understanding. Unlike Narrow AI, AGI would have cognitive flexibility comparable to human intelligence, but it has yet to be achieved [4, 20, 23].

The field of AI has encountered significant challenges, notably during the "AI winter" of the 1970s and 1980s, when limitations in computational power and data management hindered progress. However, advancements in algorithms, neural networks, and computational capabilities in the 1990s spurred a resurgence in AI research and development. Currently, AI is profoundly impacting education and training, transforming the processes of knowledge acquisition, instruction, and application. [1, 5, 35].

Overall, AI stands as a transformative force, continuously expanding the boundaries of technological possibilities and reshaping the future of human-machine interaction across diverse domains.

B. Transformative Applications of AI in Education

AI has emerged as a transformative force in the education sector, offering a range of innovative solutions that enhance traditional teaching, training and learning processes. Its applications are diverse, including tools designed to improve the efficiency, personalization, and overall quality of education [6].

AI has fundamentally reshapes educational practices by enabling more personalized, independent, and immersive learning experiences through advanced data analysis models. ML algorithms tailor educational content by analyzing profiles, allowing for customized learning pathways that adapt to each individual's unique needs [7].

The evolution of AI in education has progressed from basic computer-based systems to advanced web-based intelligent platforms, incorporating technologies such as humanoid robots and Chatbots [36]. These technologies serve distinct functions across three primary perspectives:

Learner-Facing AI: Systems like intelligent tutoring systems help guide trainees through subject matter mastery by providing adaptive learning paths.

Teacher-Facing AI: AI tools automate administrative tasks, such as assessment and plagiarism detection, while offering insights into student progress, significantly reducing the workload for educators.

System-Facing AI: AI supports institutional management by offering data-driven insights, enabling administrators to track patterns such as student retention rates and academic performance across departments.

This multi-faceted integration of AI in education optimizes learning outcomes while streamlining both instructional and administrative functions [8, 9].

Key areas of AI integration in education include:

Personalized Learning: AI enables personalized learning by analyzing scholars learning styles, strengths, and weaknesses, allowing for tailored educational content that meets individual needs, thus enhancing engagement and success [37, 38].

Adaptive Learning: AI-driven adaptive learning systems adjust the difficulty of content in real-time based on trainee performance, maintaining engagement by advancing proficient learners and providing additional support to those struggling [8, 39].

Chatbots: AI-powered conversational agents offer real-time support, answering queries, providing feedback, and delivering progress notifications. They enhance the learning experience by fostering interactivity and maintaining motivation [7, 37].

Intelligent Tutors: These AI-powered systems simulate personalized tutoring through ML algorithms and neural networks. They adapt to individual needs, providing tailored content and real-time feedback. Offering 24/7 support, these tutors foster independent learning and assist scholar with complex topics. Intelligent tutors enhance instructional quality by reducing workload educators' while AI-powered dashboards provide insights into trainee engagement, progress, and emotional responses, making them effective for large-scale distance education [8, 37, 40, 41].

Enhanced Content Creation: AI aids educators in generating interactive and immersive content, such as virtual labs and adaptive textbooks, which promote deeper engagement with complex subjects [42, 43].

Grading and Assessment: AI use technologies like NLP and automated speech recognition to evaluate trainee responses. It streamlines grading, providing faster, objective feedback for written and oral tasks. By automating routine assessments, AI frees educators to focus on personalized student interactions, improving teaching efficiency and learning outcomes. Additionally, AI ensures consistent grading, which is especially valuable in large-scale assessments where manual evaluation may be impractical [32, 37].

Predictive Analytics: AI leverages predictive analytics to identify students at risk of academic failure, allowing institutions to provide timely interventions and support, improving student success rates.

Language Learning: AI-driven language learning applications offer real-time translation and pronunciation feedback, significantly enhancing the effectiveness and immersion of language acquisition [44, 45].

Virtual and Augmented Reality: VR/AR, integrated with AI, offers immersive learning experiences through interactive virtual environments. Intelligent Virtual Reality (IVR) systems incorporate features from Intelligent Tutoring Systems (ITS), simulating real world or abstract educational scenarios. Virtual agents serve as instructors or peers, providing personalized feedback and guidance. This fusion of AI, VR, and AR supports experiential learning, fostering deeper understanding and making education more dynamic and engaging [8, 44, 46].

Content Recommendation: AI systems provide personalized content recommendations based on learner interests and progress, encouraging deeper subject exploration and more effective learning outcomes [45].

Accessibility: AI-based tools improve accessibility in education by offering features such as speech recognition and text-to-speech, ensuring scholars with disabilities have equal learning opportunities [47].

Education Analytics: AI facilitates data-driven decision-making in educational administration by analyzing enrollment, attendance, and performance data, leading to improved resource allocation and strategic planning [47, 48].

Learning Analytics Dashboards: AI-powered dashboards offer educators real-time insights into student engagement, progress, and performance. These tools help identify at-risk students and areas where learners may need additional support [49].

Automated Content Creation: Generative AI, exemplified by OpenAI's ChatGPT, is transforming educational materials by enabling personalized learning experiences. Its ability to generate human-like text supports automated question generation and personalized learning resources. This innovation aligns with growing educational emphasis on individualized approaches, reflecting Bill Gates' view that the future of education will rely heavily on personalized methodologies powered by AI [50].

AI-based proctoring: AI-driven proctoring tools are essential for maintaining academic integrity in remote exams. Using technologies like computer vision and ML, these systems monitor trainees via webcams, detecting irregular behaviors indicating cheating. Common proctoring methods include live proctoring, where human proctors observe in real time; automated proctoring, which relies solely on AI to flag anomalies; and recorded proctoring, which allows for post-exam reviews. These approaches ensure robust and continuous monitoring, enhancing the security and fairness of online assessments [18, 51].

Sentiment Analysis: AI-driven sentiment analysis in education uses ML, facial recognition, and affective computing to detect and analyze scholars' emotions during learning activities. By using Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs), these systems adapt learning environments to individual emotional needs in real-time, enhancing personalized learning and improving pedagogical strategies [52].

AI-powered tools facilitate personalized instruction, deliver real-time feedback, and offer data-driven insights, enhancing the overall effectiveness and engagement of learning environments. While the growing adoption of AI technologies is reshaping student-teacher interactions, enabling more tailored educational experiences. However, AI integration must be responsible, following legal, regulatory, and ethical standards to ensure legitimacy [10, 53]. When aligned with these standards, AI offers transformative opportunities for personalized learning, significantly improving academic outcomes.

C. The Impact of AI on Education

The implementation of AI in education has significantly transformed learning, teaching practices, and the structure of educational systems [54]. Studies highlight the positive influence of AI-based tools, particularly their widespread adoption across training, instruction, learning, and administrative operations.

According to Chen *et al*. [36], educational institutions have widely embraced AI for diverse functions. AI tools have streamlined administrative tasks like reviewing and grading assignments with greater efficiency, leading to improved teaching quality. Moreover, AI's adaptability has allowed for the customization of curricula and educational content to meet individual needs, resulting in higher engagement and retention, ultimately enhancing the learning experience.

In his research article, "Exploring the Impact of Artificial Intelligence in Teaching and Learning of Science: A Systematic Review of Empirical Research," Firas Almasri emphasizes the transformative role of AI in education, particularly in instructional practices, assessments, and administration. AI has proven instrumental in science education, providing benefits such as improved learning environments, automated assessments, and enhanced trainee performance predictions. Teachers reported positive perceptions of AI's effectiveness in fostering engagement, comprehension, and motivation—findings supported by studies from Ahmet Gocen *et al*., Fati Tahiru and Lamrabet *et al*. and others [48, 55–58].

However, challenges persist, including AI's limitations in grasping complex subject, adapting to diverse educational contexts, and inconsistencies across AI models. Ethical concerns, particularly related to data privacy and responsible use, further complicate AI's integration into education. To fully leverage AI's potential, educators and policymakers must carefully evaluate and adapt these technologies while adhering to ethical standards [47].

In conclusion, AI has had a transformative impact on education, especially in administration, instruction, and personalized learning [36]. As AI technology continues to evolve, its application in education is expected to grow more sophisticated. Addressing challenges, such as algorithmic bias and privacy concerns, will open new opportunities for enriching training, teaching and learning. Ongoing research, innovation, and reform of educational models are essential for maximizing AI's benefits in the educational landscape [19].

D. Integration of AI-Based Tools in Initial Teacher Training: Insights from Recent Studies

Recent research highlight the critical importance of integrating AI-based tools across various sectors [11], particularly in education. This integration can enhance teaching and training methodologies, streamline administrative tasks, and personalize learning experiences [12, 13].

The impact of AI on the education system is undeniable, marking a transformative shift that influences the teaching profession. As AI evolves, it has the potential to revolutionize education further, positioning itself as a central force in shaping the future of learning and pedagogical practices [6]. From initial teacher training through to lifelong learning, AI represents a significant shift in conventional approaches to pedagogy [37]. AI introduces tools that enrich educator experience [6]. As articulated in the Beijing Consensus on AI and education, it is critical to: "*Plan and develop coherent system-wide strategies for AI in education that are aligned and integrated with education policies, within a lifelong learning perspective*" [14]. Despite these promising advancements, while AI offers great potential, it also presents opportunities and challenges, making teacher preparation for this technological shift essential [37]. Factors such as AI-related anxiety, perceived usefulness, readiness, and teacher attitudes are key determinants that shape teachers' behavioral intentions to incorporate AI in their teaching practices. Research findings indicate that these elements affect the formation of teaching intentions among educators. To facilitate this integration, there is a pressing need for comprehensive training programs focused on relevant AI topics for both future and experienced educators. Moreover, the integration of AI into education not only fosters enthusiasm but also presents significant opportunities for schools [15]. However, new developments, contexts, and impacts necessitate vigilant monitoring and critical reflection within the classroom environment. AI can be effectively utilized across various interdisciplinary domains, thereby enabling the design of educational curricula at all levels of education. It is essential to assess the legal, ethical, pedagogical, psychological, and sociological implications associated with implementing AI in educational settings [16]. Effective application of AI in teaching and learning processes requires a strategic approach to teacher preparation, including fostering AI literacy, incorporating AI into initial teacher training programs, and providing ongoing professional development [37].

The findings about the integration of AI into Continuing Professional Development (CPD) programs demonstrate a significant positive impact by providing intelligent tools that can personalize training programs to align with experienced teachers' individual needs, preferences, and proficiency levels. Moreover, incorporating AI as a central topic within CPD is crucial for enhancing teachers' AI literacy, enabling them to effectively utilize AI-based tools in educational settings. This approach is essential not only for current educators but also for future teachers, as it equips them to engage with the technological advancements that are reshaping the educational landscape [4].

Advancements in AI present substantial opportunities for the professional development of future educators. A majority of educators, trainee teachers, and administrative personnel recognize the pivotal benefits offered by AI-based tools, particularly in facilitating their integration from initial teacher training to lifelong learning. The findings of this study reveal that the successful AI integration is closely linked to trainee teachers' perceptions of its usefulness, ease of use, and overall satisfaction with these technologies [59]. Furthermore, complementary research underscores the critical roles of perceived usefulness, social influence, personal innovation, and trust in fostering AI adoption within educational settings. Collectively, these factors highlight the multifaceted nature of AI integration, emphasizing the need for targeted strategies to enhance educator engagement with these transformative tools [60].

The findings of recent studies indicate that AI-based teacher training has the potential to enhance knowledge. However, at this stage, integrating AI technology should complement traditional teaching methods [61]. These insights are relevant to educators, parents, and school and university administrators, offering valuable considerations for strategic planning in the implementation of AI in education, particularly when determining its role and scope within specific areas of study [62]. Therefore, it is imperative to prioritize the integration of AI within educational institutions [16], ensuring comprehensive training that equips future teachers with the skills to navigate and utilize AI and its tools effectively.

Although international perspectives on integrating AI-based tools from initial teacher training to lifelong learning are well-developed [17], there is a significant gap in research on this topic within the Moroccan educational context. Several factors contribute to this discrepancy. The integration of AI into the educational system is relatively new in Morocco, and many educational institutions face limited access to AI technologies and resources, hindering both the practical implementation and the study of these tools. Additionally, the teacher-training curriculum in Morocco has not yet fully incorporated AI-related content or AI-based tools, leading to a lack of exposure and awareness among prospective teachers. Furthermore, to the best of our knowledge, no scientific studies in the Moroccan context, particularly those involving future teachers during their initial training, have examined perceptions regarding the integration of AI-based tools, especially from the perspective of lifelong learning. In light of these challenges, it is evident that multiple factors may influence the intention to integrate AI-based tools in the Moroccan educational landscape.

In response to these research gaps, this study aims to explore the factors influencing perceptions regarding the necessity of integrating AI-based tools from the initial training of future Moroccan teachers. Drawing on the identified research void and an extensive review of the existing literature, this study addresses three key research questions.

Research questions:

1) To what extent do future and experienced teachers, with a satisfactory level of knowledge of AI-based tools, perceive the integration of these tools from initial teacher training as necessary?
2) How does teaching experience, measured by the number of years, influence teachers' perceptions of the necessity to integrate AI-based tools from initial teacher training?
3) What external knowledge-related factors significantly impact teachers' perceptions of the necessity to integrate AI-based tools from initial teacher training?

III. Materials and Methods

A. General Background

This study was conducted during the fall semester of the 2023–2024 academic year. A quantitative approach was adopted, involving the design and development of a questionnaire that underwent rigorous reliability and validity testing. After data collection, a mixed-methods approach was implemented, integrating correlation analysis and both exploratory and confirmatory factor analyses.

Correlation analysis was performed to examine the relationships between study variables, while EFA and CFA were utilized to identify latent constructs and organize study elements accordingly. Additionally, quantitative analyses were conducted to provide a detailed understanding of the data. Frequency analysis was employed to evaluate the distribution of participants' responses, while contingency tables and the Chi-Square Test were applied to summarize and interpret categorical data, revealing relationships between variables and identifying trends.

To further investigate the influence of independent variables on the dependent variable—perceived necessity for the integration of AI-based tools in initial teacher training—ordinal logistic regression was employed. This analysis provided insights into the strength and significance of the relationships between predictors and the outcome variable.

B. The Sample

The sample for this study comprised two distinct groups. The first group consists of 243 future teachers randomly selected from the third year of initial teacher training at the ENS of Fez representing primary, scientific, and literary specializations. The second group includes 238 experienced teachers working in Moroccan public schools within the Fez-Meknes region, specializing in the same areas. A snowball sampling technique was employed to recruit experienced teachers. While this method offers advantages in accessing specific populations, it is important to recognize the potential sampling bias introduced by social networks. Nevertheless, considerable efforts have been made to ensure a diversity of profiles within this subsample.

Participants were invited to participate in the survey, and all data was collected anonymously. From 500 potential participants, we obtained and analyzed 482 complete responses, yielding a response rate of 96.40%. Of these, 50.6% ($n = 244$) were prospective teachers in their 3rd year of initial training, 23.7% ($n = 114$) were teachers with 1 to 4 years of teaching experience, and 25.8% ($n = 124$) were teachers with 5 to 10 years of teaching experience.

In terms of gender distribution, 168 participants (34.9%) were male and 314 (65.1%) were female. Among them, 112 specialized in primary education, 138 in science, and 232 in humanities. All participants voluntarily agreed to participate in this study.

The majority of prospective teachers were 19 to 20 years old, with an average age of 19.5 years. Most of them only had a high school diploma (BAC), and less than 10% held a university general studies diploma (BAC + 2).

Regarding experienced teachers, 37.82% of participants held a BAC + 3 level diploma. The majority, or 50.42%, held a BAC + 5 level diploma, and 11.76% of participants held a PhD (Table 1–2).

It is important to note that the sample may not fully represent the broader population of prospective and experienced teachers in Morocco. Further research is needed to generalize findings.

Table 1. Demographic characteristics of sample

Variable	Demographic	Frequency	Percent (%)	Valid Percent (%)
Genre	Male	168	34.9	34.9
	Female	314	65.1	100.0
Years of teaching experience	[a] Experience0	244	50.6	50.6
	Experience1–4	114	23.7	74.3
	Experience5–10	124	25.7	100.0
Specialty	Primary	112	23.3	23.3
	Scientist	138	28.5	51.8
	Literary	232	48.2	100.0

[a] Represents third-year future teachers in initial training.

Table 2. Repartition of our study's

Variable	Demographic		Frequency	Percent (%)	Valid Percent (%)
Future teachers	Diploma	BAC	30	12.35	91.26
		BAC + 2	213	87.65	8.74
	Age range	19–20	243	100	100
Experienced teachers	Diploma	BAC + 3	90	37.82	37.82
		BAC + 5	120	50.42	50.42
		PhD	28	11.76	11.76
	Age range	20–30	238	100	100

C. Instrument and Procedures

A quantitative research methodology was employed for this study. Data were collected through a structured questionnaire designed to yield measurable and statistically analyzable information. The instrument was derived from and inspired by the Technology Acceptance Model (TAM) [63] and the Theory of Reasoned Action (TRA) [64], consisted of three sections with a total of 16 items. These theoretical frameworks provided a robust foundation to explore participants' knowledge, utilization, and perceptions of AI-based tools, as well as the factors influencing their acceptance and perceived necessity for integration in teacher training.

The initial section collected demographic data to characterize the study participants. Information pertaining to gender, years of teaching experience, specialization, age, and educational background was gathered. The second section concentrated on participants' knowledge and utilization of emerging technologies and AI-based tools. Finally, the third section examined perceptions of the integration and potential of these tools in education. A three-point Likert scale was employed for both sections to quantify responses, ensuring consistency in data analysis.

Preceding the distribution, the instrument underwent rigorous development, starting with the definition of clear research objectives. Relevant and precise questions were formulated and organized into three distinct sections. A pilot test was conducted with a small, randomly selected sample of 50 participants, including 25 future teachers and 25 experienced teachers, to assess the questionnaire's clarity, comprehension, and relevance. Subsequent refinements were made based on feedback from six university professors. To ensure the questionnaire's psychometric properties, reliability analysis using Cronbach's alpha and McDonald's Omega coefficient [65], and validity analysis through EFA and CFA were conducted. Data collection was carried out in adherence to ethical and confidentiality protocols.

The questionnaire demonstrated high reliability, with a Cronbach's alpha coefficient of 0.892 and a McDonald's Omega coefficient of 0.894 (Table 3). These values indicate excellent internal consistency among the questionnaire items, in accordance with established psychometric standards.

Table 3. Reliability statistics

Scale	Mean	SD	Cronbach's α	McDonald's ω
Scale	2.23	0.418	0.892	0.894

D. Data Collection

Prior to data collection, the questionnaire underwent a rigorous development process, which included the two important preliminary steps.

1) Initial testing phase: This phase assessed the questionnaire's clarity, comprehension, and feasibility.
2) Pilot test: A pilot test involving 25 future teachers and 25 experienced teachers was implemented to gather feedback on the instrument's design.

To accommodate the distinct characteristics of the two participant groups, paper-based questionnaires were administered to future teachers, while experienced teachers completed the questionnaire online using Google Forms. This approach aimed to maximize participant engagement and data collection efficiency.

3) Data analysis

Data analysis was conducted using JAMOVI 2.3.28 (The jamovi project, 2023) [66], a free statistical software package. A quantitative approach was employed, incorporating frequency analysis, contingency table, and ordinal logistic regression to examine the data.

Six independent variables are considered in our study:

- **Years of teaching experience**, measured on a continuous scale (0, 1–4, 5–10 Years).
- **K1_LIET**: Level of interest in emerging technologies, measured on a Likert scale of 1–3 (Not at all interested, interested, Very interested).
- **K2_LMET**: Level of mastery of emerging technologies, measured on a Likert scale of 1–3 (Weak, Moderately, Alright).
- **K3_LFAI**: Level of familiarity with the concept of AI, measured on a Likert scale of 1–3 (Not at all familiar, Familiar, Yes very familiar).
- **K4_LKAIT**: Level of knowledge of AI-based tools, measured on a Likert scale of 1–3 (No way, Moderately, Yes perfectly).
- **K5_LUSTPL**: Level of utilization of smart tools in personal life, measured on a Likert scale of 1–3 (Rarely, From time to time, Every day).

The study investigated the following hypotheses:

H1: Future teachers with satisfactory knowledge of AI-based tools are more likely to perceive their integration from initial teaching training as necessary.

H2: Experienced teachers with satisfactory knowledge of AI-based tools are more likely to perceive their integration from initial teaching training as necessary.

H3: The participants' perception of the necessity to integrate AI-based tools from initial teaching training is significantly influenced by their years of teaching experience.

H4: Several external independent variables related to knowledge significantly influences the perception of the necessity to integrate AI-based tools from initial teaching training.

IV. Result and Discussion

A. Result

1) Correlation analysis of study variables

The correlation matrix was utilized to evaluate the strength and direction of relationships between variables. Pearson *R*-values demonstrated strong inter-item correlations, suggesting cohesion among constructs. Statistically significant *p*-values (all < 0.001) confirmed that these correlations were not due to chance, thus supporting the robustness and reliability of the constructs.

In this matrix (Table 4), correlation values range from 0.193 to 0.698. All variables exhibit positive correlations with each other, though the strength of these correlations varies. For instance, K2_LMET and K3_LFAI show a strong positive correlation of 0.698, suggesting that higher scores on K2_LMET are associated with higher scores on K3_LFAI. Conversely, P1_AIUSD (Do you think AI should be used in the field of education?) and P5_ROL (How do you perceive the role of the teacher in a learning environment supported by AI?) have a weaker positive correlation of 0.193 and, indicating that while there is a positive relationship, it is relatively weak compared to others. Overall, the correlation matrix indicates that positive relationships exist among all variables, but the strength of these relationships differs.

2) Exploratory factor analysis

EFA was used as an initial step to explore the underlying structure of the observed variables without imposing a predefined framework. This analysis enabled the identification of coherent factors, thereby ensuring that the constructs were well-defined and adequately represented by the data. The results of EFA informed subsequent steps, including Confirmatory Factor Analysis (CFA).

Prior to conducting the EFA, the normality assumption of the data was assessed. The Shapiro-Wilk test indicated a significant departure from normality ($p < 0.001$), suggesting that the data were not normally distributed. Bartlett's test of Sphericity was significant ($\chi^2 = 2610$, $p < 0.001$), confirming the appropriateness of factor analysis. The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO = 0.922) and the Measure of Sampling Adequacy (MSA) values for individual items (ranging from 0.858 to 0.920) indicated that the data were suitable for factor analysis.

Principal axis factoring with Promax rotation was employed to extract and rotate factors. Two factors with eigenvalues greater than 1 were retained (Factor 1 = 3.12 and Factor 2 = 1.96), explaining 39.1% of the total variance. The factor loadings for the items on each factor were examined, with values greater than 0.400 considered significant (Table 5). Cronbach's alpha and McDonald's Omega coefficients were calculated to assess the internal consistency of the items within each factor, revealing acceptable reliability (Table 6).

Table 4. Repartition of our study's

Variable	Correlation	K1_ LIET	K2_ LMET	K3_ LFAI	K4_ LKAIT	K5_ LUSTPL	P1_ AIUSD	P2_ QLT	P3_ FCT	P4_ HTR	P5_ ROL	P6_ ITG
K1_LIET	Pearson's *r*	—										
	df	—										
	p-value	—										
	N	—										
K2_LMET	Pearson's *r*	0.612	—									
	df	480	—									
	p-value	<0.001	—									
	N	482	—									
K3_LFAI	Pearson's *r*	0.566	0.698	—								
	df	480	480	—								
	p-value	<0.001	<0.001	—								
	N	482	482	—								
K4_LKAIT	Pearson's *r*	0.501	0.631	0.635	—							
	df	480	480	480	—							
	p-value	<0.001	<0.001	<0.001	—							
	N	482	482	482	—							
K5_LUSTPL	Pearson's *r*	0.480	0.539	0.568	0.591	—						
	df	480	480	480	480	—						
	p-value	<0.001	<0.001	<0.001	<0.001	—						
	N	482	482	482	482	—						
P1_AIUSD	Pearson's *r*	0.520	0.442	0.513	0.458	0.570	—					
	df	480	480	480	480	480	—					
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	—					
	N	482	482	482	482	482	—					
P2_QLT	Pearson's *r*	0.300	0.350	0.369	0.297	0.346	0.389	—				
	df	480	480	480	480	480	480	—				
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—				
	N	482	482	482	482	482	482	—				
P3_FCT	Pearson's *r*	0.262	0.314	0.364	0.327	0.258	0.310	0.503	—			
	df	480	480	480	480	480	480	480	—			
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—			
	N	482	482	482	482	482	482	482	—			
P4_HTR	Pearson's *r*	0.244	0.303	0.348	0.293	0.334	0.300	0.412	0.367	—		
	df	480	480	480	480	480	480	480	480	—		
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—		
	N	482	482	482	482	482	482	482	482	—		
P5_ROL	Pearson's *r*	0.233	0.298	0.310	0.253	0.239	0.193	0.287	0.210	0.318	—	
	df	480	480	480	480	480	480	480	480	480	—	
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—	
	N	482	482	482	482	482	482	482	482	482	—	
P6_ITG	Pearson's *r*	0.293	0.308	0.269	0.260	0.219	0.215	0.273	0.274	0.293	0.251	—
	df	480	480	480	480	480	480	480	480	480	480	—
	p-value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	—
	N	482	482	482	482	482	482	482	482	482	482	—

Table 5. Factor loadings

Items	KNOWLEDGE	PERCEPTION	Uniqueness
K2_LMET	0.954		0.279
K3_LFAI	0.787		0.329
K4_LKAIT	0.784		0.417
K1_LIET	0.624		0.492
K5_LUSTPL	0.513		0.470
P1_AIUSD		0.960	0.141
P2_QLT		0.753	0.484
P3_FCT		0.678	0.593
P4_HTR		0.619	0.640
P5_ROL		0.411	0.781
P6_ITG		0.401	0.788

The extracted factors were labeled "Knowledge" and "Perception" based on the pattern of item loadings. Notably, the inter-factor correlation was 0.687 (Table 7), indicating a strong positive relationship between these factors. This suggests that as knowledge of AI tools increases, so does the perception of their integration, usefulness and relevance. Model fit indices were examined to assess the adequacy of the factor solution. The Root Mean Square Error of Approximation (RMSEA) was 0.0462, indicating a good fit of the model to the data. The Tucker-Lewis Index (TLI) of 0.968 suggested a satisfactory fit (Table 8).

Table 6. Scale reliability statistics "Factor"

Factor	Mean	SD	Cronbach's α	McDonald's ω
KNOWLEDGE	2.05	0.526	0.873	0.876
PERCEPTION	2.34	0.409	0.722	0.731

Table 7. Inter-factor correlations

Factor	KNOWLEDGE	PERCEPTION
KNOWLEDGE	------	0.687
PERCEPTION		—

Table 8. EFA model fit measures

RMSEA	Lower	Upper	TLI	BIC	χ^2	df	p
0.0462	0.0321	0.0604	0.968	−174	85.3	42	< 0.001
RMSEA 90% CI				Model Test			

3) *Confirmatory factor analysis*

CFA was conducted to confirm the alignment of the observed data with the hypothesized measurement model. This step ensured that the constructs measured in the study were valid and reliable [67, 68]. The results, presented in Table 9, indicate that the two latent factors are significantly associated with their respective sets of observed variables. A strong positive covariance (0.771) between the factors (Table 10) suggests a substantial relationship between knowledge and perception.

Model fit was evaluated using the following indices (Table 11): CFI = 0.980, TLI = 0.974, RMSEA = 0.0456 and SRMR = 0.0296. These values collectively suggest a good fit of the model to the data, with the RMSEA falling slightly above the conventional cutoff of 0.05.

Table 9. CFA Factor loadings

Factor	Indicator	Estimate	SE	Z	p	Stand. Estimate
KNOWLEDGE	K1_LIET	0.465	0.0279	16.64	<0.001	0.694
	K2_LMET	0.492	0.0230	21.42	<0.001	0.829
	K3_LFAI	0.527	0.0245	21.56	<0.001	0.832
	K4_LKAIT	0.535	0.0280	19.11	<0.001	0.767
	K5_LUSTPL	0.439	0.0264	16.63	<0.001	0.695
PERCEPTION	P1_AIUSD	0.451	0.0337	13.39	<0.001	0.629
	P2_QLT	0.424	0.0287	14.78	<0.001	0.689
	P3_FCT	0.378	0.0282	13.40	<0.001	0.633
	P4_HTR	0.361	0.0283	12.79	<0.001	0.607
	P5_ROL	0.282	0.0309	9.14	<0.001	0.454
	P6_ITG	0.290	0.0311	9.34	<0.001	0.462

Table 10. Factor covariances

Covariance	Estimate	SE	Z	p	Stand. Estimate
KNOWLEDGE—PERCEPTION	0.771	0.0343	23.1	<0.001	0.771

Table 11. CFA Fit measures

CFI	TLI	SRMR	RMSEA	RMSEA 90% CI Lower	RMSEA 90% CI Upper	AIC	BIC
0.980	0.974	0.0296	0.0456	0.0296	0.0613	7569	7698

4) *Frequency analysis*

The findings related to the knowledge factor indicate a substantial level of interest in emerging technologies among both future teachers and in-service teachers. Over half of the participants (53.3%) expressed interest, while 30.1% indicated a high level of interest. This significant interest correlates with the observed proficiency in emerging technologies, with 19.1% demonstrating an advanced level and 64.7% exhibiting an intermediate level. Furthermore, the results reveal a high level of familiarity with the concept of AI, with over 78% of respondents indicating familiarity or a high degree of familiarity. Regarding knowledge of intelligent teaching tools, nearly half of the respondents reported an average level of understanding, while more than one-third possessed in-depth knowledge. Additionally, over 18% of participants reported regular personal use of AI-powered tools, while 60% indicated occasional use, as detailed in Table 12 and visualized in Fig. 1.

Table 12. Frequency of KNOWLEDGE factor results

Statement	K1_LIET (Level of interested in emerging technologies)	
Likert Scale	**Counts**	**Percent (%)**
Not at all interested	80	16.6
interested	257	53.3
Very interested	145	30.1
Statement	**K2_LMET (Level of mastery of emerging technologies)**	
Weak	78	16.2
Moderately	312	64.7
Alright	92	19.1
Statement	**K3_LFAI (Level of familiarity with the concept of AI)**	
Not at all familiar	104	21.6
Familiar	288	59.8
Yes, very familiar	90	18.7
Statement	**K4_LKAIT (Level of knowledge of AI-based Tools)**	
No way	85	17.6
Moderately	236	49.0
Yes perfectly	161	33.4
Statement	**K5_LUSTPL (Level of utilization of smart tools in personal life)**	
Rarely	104	21.6
From time to time	289	60.0
Every day	89	18.5

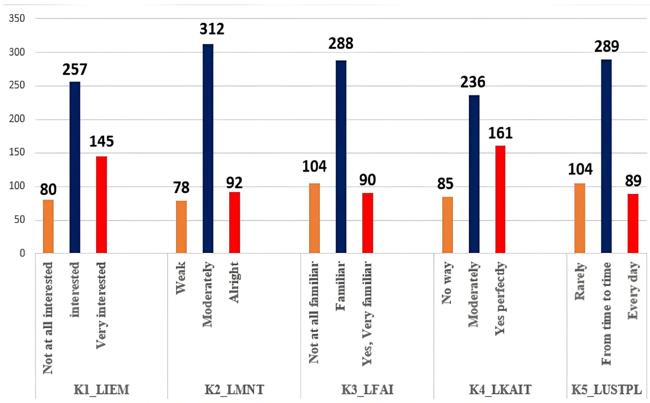

Fig. 1. Frequency distribution of responses for KNOWLEDGE-related items.

Concerning the PERCEPTION factor, as shown in Table 13 and represented in Fig. 2, a significant majority (78.8%) of participants expressed the necessity of using AI in education. While opinions were divided regarding AI's impact on teaching and learning quality (46.1% certain, 46.9% probable), a majority (58.5%) believed AI would facilitate teaching tasks. To address cognitive heterogeneity, 55% perceived AI as helpful, with 38% strongly agreeing. Most participants, with only 7.9%

suggesting a diminished role in AI-rich environments, deemed the teacher's role important. The need for integrating AI-based tools from initial teacher training was affirmed by a majority, with only 8.7% disagreeing.

5) Contingency Table Analysis and Chi-Square Test

To gain a deeper understanding of the factors influencing educators' perceptions of integrating AI and its tools from initial teacher training, we will examine the relationships between the dependent variable (P6_ITG) and several independent variables:

- P6_ITG = Do you think AI should be integrated from the initial training of future teachers?
- Years of teaching experience.
- Level of interest in emerging technologies (K1_LIET).
- Level of mastery of emerging technologies (K2_LMET).
- Level of familiarity with the concept of AI (K3_LFAI).
- Level of knowledge of AI-based tools (K4_LKAIT).
- Level of utilization of smart tools in personal life (K5_LUSTPL).

A comprehensive analysis will be conducted using a contingency table to analyze and summarize tabular data, enabling a clearer understanding of how variables interacted. The Chi-square test assessed the significance of relationships, while Cramer's V and Gamma provided measures of association strength and direction. This combination of tests was instrumental in identifying trends and highlighting meaningful patterns in the data.

- Relationships between P6_ITG and Years of teaching experience.

Table 13. Frequency of KNOWLEDGE factor results

Statement	P1_AIUSD (Do you think AI should be used in the field of education?)	
Likert scale	**Counts**	**Percent %**
Not really	102	21.2
Yes maybe	229	47.5
Yes, absolutely	151	31.3
Statement	**P2_QLT (Do you think AI can improve the quality of teaching and learning performance?)**	
Slightly	34	7.1
Probably	226	46.9
Certainly	222	46.1
Statement	**P3_FCT (Do you think intelligent tools can facilitate teaching tasks?)**	
Slightly	26	5.4
Probably	174	36.1
Certainly	282	58.5
Statement	**P4_HTR (Do you think AI can help manage the cognitive heterogeneity of learners?)**	
Not really	34	7.1
Maybe	265	55.0
Yes, Absolutely	183	38.0
Statement	**P5_ROL (How do you perceive the role of the teacher in a learning environment supported by AI?)**	
Not beneficial	38	7.9
Quite beneficial	234	48.5
Very beneficial	210	43.6
Statement	**P6_ITG (Do you think AI-based tools should be integrated from the initial training of future teachers?)**	
Not at all necessary	42	8.7
Quite necessary	239	49.6
Very necessary	201	41.7

Table 14 presents a contingency table analysis examining the relationship between years of professional experience and perceived necessity of AI-based tools integration from initial teacher training. Observed frequencies of educators across different experience levels selecting various degrees of necessity were compared to expected frequencies under the assumption of independence.

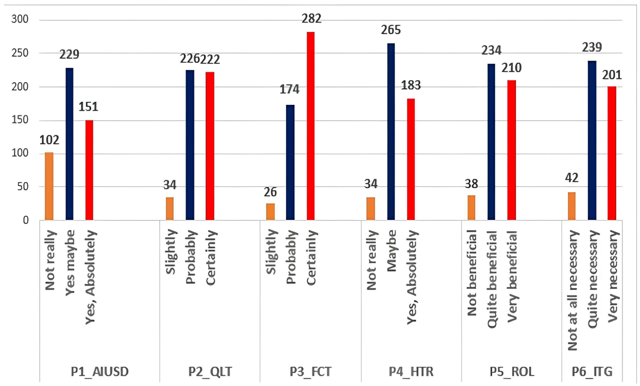

Fig. 2. Frequency distribution of responses for PERCEPTION-related item.

Table 14. Contingency table-chi-square- P6_ITG-Years of teaching experience

Dependent variable		**Years of teaching Experience**			
P6_ITG		**0**	**1–4**	**5–10**	**Total**
Not at all necessary	Observed	15	11	16	42
	Expected	21.2	9.93	10.9	42.0
	%	3.1	2.3	3.3	8.7
Quite necessary	Observed	125	57	57	239
	Expected	120.5	56.53	62.0	239.0
	%	25.9	11.8	11.8	49.6
Very necessary	Observed	103	46	52	201
	Expected	101.3	47.54	52.1	201.0
	%	21.4	9.5	10.8	41.7
Total	Observed	243	114	125	482
	Expected	243.0	114.00	125.0	482.0
	%	50.4 %	23.7 %	25.9 %	100 %
χ^2 Tests	**Value**	**df**	***p***		
χ^2	4.96	4	0.291		
N	482				
Cramer's V	0.0717				

A chi-square test yielded a non-significant result ($\chi^2 = 4.96$, $p = 0.291$), indicating no statistically significant association between years of professional experience and perceived necessity of AI-based tools integration. Cramer's V of 0.0717 further supports this finding, revealing a negligible effect size.

These results indicate that perceptions of the necessity of integrating AI-based tools from initial teacher training are relatively consistent across different levels of teaching experience. Regardless of their years of professional experience, the majority of educators consider this integration to be necessary.

- Relationships between P6_ITG and K1_LIET.

This analysis explores the relationship between educators' level of interest in emerging technologies and their perceptions regarding the necessity of integrating AI-based tools from initial teacher training. A contingency table analysis (Table 15) reveals a statistically significant positive association between these two variables. Specifically, educators who exhibit a higher level of interest in emerging technologies (20.7% interested, 17.4/% very interested) are more inclined to view the integration of AI tools as "very necessary" compared to those with lower interest (3.9%).

The chi-square test ($\chi^2 = 48.9$, $p < 0.001$) corroborates this strong and statistically significant association. Moreover, the Gamma coefficient (0.438) indicates a moderate positive relationship between the two variables. This suggests that educators with a greater level of interest in emerging technologies are significantly more likely to perceive the integration of AI-based tools as essential in initial teacher training.

Table 15. Contingency table-chi-square- P6_ITG-K1_LIET

Dependent variable		**K1_LIET**			
P6_ITG		**Not at all interested**	**Interested**	**Very interested**	**Total**
Not at all necessary	Observed	19	18	5	42
	Expected	6.97	22.4	12.6	42.0
	%	3.9	3.7	1.0	8.7
Quite necessary	Observed	44	139	56	239
	Expected	39.67	127.4	71.9	239.0
	%	9.1	28.8	11.6	49.6
Very necessary	Observed	17	100	84	201
	Expected	33.36	107.2	60.5	201.0
	%	3.5	20.7	17.4	41.7
Total	Observed	80	257	145	482
	Expected	80.00	257.0	145.0	482.0
	%	16.6	53.3	30.1	100.0
χ^2 Tests	**Value**	**df**	***p***		
χ^2	48.9	4	<0.001		
N	482				
Gamma	**SE**	**Lower**	**Upper**		
0.438	0.0624	0.316	0.561		
	95% Confidence Intervals				

These findings underscore the importance of interest in emerging technologies as a key factor influencing educators' perceptions of AI-based tools integration. Consequently, targeted training and awareness initiatives focusing on emerging technologies could play a crucial role in enhancing the perceived necessity of AI tools integration in teacher training programs.

- Relationships between P6_ITG and K2_LMET.

This contingency table (Table 16) analyzes the relationship between educators' level of mastery of emerging technologies and their perceptions regarding the necessity of integrating AI-based tools from initial teacher training. It reveals a statistically positive association between these variables. Specifically, educators with a high level of technological proficiency (38%) were significantly more likely to perceive AI-based tools integration as "very necessary" compared to those with lower proficiency (4.1%).

The chi-square test analysis ($\chi^2 = 60.2$, $p < 0.001$) confirms a strong and statistically significant association. The findings indicate a clear trend: the higher the educators' mastery of emerging technologies, the stronger their perception of the necessity of integrating AI-based tools from initial teacher training. In addition, the Gamma coefficient (0.495) indicates a moderate positive association between these variables. Clearly, teachers who have a greater mastery of emerging technologies are more likely to consider this integration as necessary from initial training.

These results suggest that enhancing educators' technological competencies at all levels could be a strategic approach to fostering the adoption of AI tools in teacher education programs. By increasing technological proficiency, institutions can potentially strengthen the perceived necessity for AI tools integration from the outset of teacher training.

Table 16. Contingency table-chi-square- P6_ITG-K2_LMET

Dependent variable		**K2_LMET**			
P6_ITG		**Weak**	**Moderately**	**Alright**	**Total**
Not at all necessary	Observed	20	19	3	42
	Expected	6.80	27.2	8.02	42.0
	%	4.1	3.9	0.6	8.7
Quite necessary	Observed	40	171	28	239
	Expected	38.68	154.7	45.62	239.0
	%	8.3	35.5	5.8	49.6
Very necessary	Observed	18	122	61	201
	Expected	32.53	130.1	38.37	201.0
	%	3.7	25.3	12.7	41.7
Total	Observed	78	312	92	482
	Expected	78.00	312.0	92.00	482.0
	%	16.2	64.7	19.1	100
χ^2 Tests	**Value**	**df**	***p***		
χ^2	60.2	4	<0.001		
N	482				
Gamma	**SE**	**Lower**	**Upper**		
0.495	0.0661	0.365	0.624		
	95% Confidence Intervals				

- Relationships between P6_ITG and K3_LFAI.

This contingency table analysis (Table 17) examines the relationship between educators' level of familiarity with AI and their perception of the necessity to integrate AI-based tools from initial teacher training. The results reveal a statistically significant positive association between these variables. Specifically, educators who are «familiar or very familiar" with AI concepts are 36.3% more likely to perceive AI integration as "Very necessary," compared to only 4.6% of those who are "not at all familiar" with AI, who tend to view AI integration as "Not at all necessary".

Table 17. Contingency table-chi-square- P6_ITG-K3_LFAI

Dependent Variable		**K3_LFAI**			
P6_ITG		**Not at all familiar**	**Familiar**	**Yes, very familiar**	**Total**
Not at all necessary	Observed	22	18	2	42
	Expected	9.06	25.1	7.84	42.0
	%	4.6	3.7	0.4	8.7
Quite necessary	Observed	56	148	35	239
	Expected	51.57	142.8	44.63	239.0
	%	11.6	30.7	7.3	49.6
Very necessary	Observed	26	122	53	201
	Expected	43.37	120.1	37.53	201.0
	%	5.4	25.3	11.0	41.7
Total	Observed	104	288	90	482
	Expected	104.00	288.0	90.00	482.0
	%	21.6	59.8	18.7	100
χ^2 Tests	**Value**	**df**	***p***		
χ^2	40.8	4	<0.001		
N	482				
Gamma	**SE**	**Lower**	**Upper**		
0.415	0.0655	0.287	0.543		
	95% Confidence Intervals				

The chi-square test ($\chi^2 = 40.8$, $p < 0.001$) confirms a strong and statistically significant association between familiarity with AI and perceived necessity for AI-based tools. The moderate positive association, reflected by a Gamma coefficient of 0.415, suggests that as familiarity with AI increases, so does the perceived necessity for its integration in teacher training.

These findings highlight the importance of enhancing educators' familiarity with AI concepts to foster a greater appreciation for the integration of AI tools in initial teacher training. To promote wider adoption and effective implementation, targeted AI awareness and training programs could be developed, ultimately supporting the advancement of educational practices in the age of digital transformation.

- Relationships between P6_ITG and K4_LKAIT.

The contingency table data (Table 18) analyzed the relationship between educators' level of knowledge of intelligent AI-based tools and their perception of the necessity of integrating these tools from initial teacher training. Specifically, educators with a higher level of knowledge are more likely to view this integration as essential. For example, 36.7% of those with perfect or moderately level of knowledge of AI-based tools considers their integration "Very necessary," whereas only 3.7% of those with no knowledge view AI integration as "Not at all necessary."

Table 18. Contingency table-chi-square- P6_ITG-K4_LKAIT

Dependent Variable		**K4_LKAIT**			
P6_ITG		**No way**	**Moderately**	**Yes perfectly**	**Total**
Not at all necessary	Observed	18	17	7	42
	Expected	7.41	20.6	14.0	42.0
	%	3.7	3.5	1.5	8.7
Quite necessary	Observed	43	135	61	239
	Expected	42.15	117.0	79.8	239.0
	%	8.9	28.0	12.7	49.6
Very necessary	Observed	24	84	93	201
	Expected	35.45	98.4	67.1	201.0
	%	5.0	17.4	19.3	41.7
Total	Observed	85	236	161	482
	Expected	85.00	236.0	161.0	482.0
	%	17.6	49.0	33.4	100
χ^2 Tests	**Value**	**df**	***p***		
χ^2	42.3	4	<0.001		
N	482				
Gamma	**SE**	**Lower**	**Upper**		
0.389	0.0643	0.263	0.515		
	95% Confidence Intervals				

The chi-square test ($\chi^2 = 42.3$, $p < 0.001$) confirms a statistically significant association, while the Gamma coefficient of 0.389 indicates a moderate positive relationship. These findings underscore that educators with greater knowledge of AI-based tools are significantly more likely to advocate for their integration from initial training.

These results emphasize the importance of enhancing educators' knowledge of AI-based tools to strengthen their perception of the necessity of their early integration in teacher training. Efforts to increase AI literacy among educators, along with the targeted training on AI tools, could therefore play a crucial role in advancing the adoption and effective implementation of AI tools in educational settings.

- Relationships between P6_ITG and K5_USTPL.

The contingency table data (Table 19) explores the relationship between the perceived necessity of integrating AI-based tools in initial teacher training and the level of utilization of smart tools in personal life. The analysis reveals that educators who use smart tools every day are more likely to view AI tools integration as "Quite necessary" (9.5%) or "Very necessary" (8.3%). In contrast, those who rarely use smart tools are less likely to perceive their integration as necessary, with only 4.8% considering it "Not at all necessary." Additionally, 28.6% of educators who use smart tools "from time to time" view AI-based tools integration as "Very necessary."

Table 19. Contingency table-Chi-square- P6_ITG-K5_USTPL

Dependent Variable		**K5_USTPL**			
P6_ITG		**Rarely**	**From time to time**	**Every day**	**Total**
Not at all necessary	Observed	23	16	3	42
	Expected	9.06	25.2	7.76	42.0
	%	4.8	3.3	0.6	8.7
Quite necessary	Observed	58	135	46	239
	Expected	51.57	143.3	44.13	239.0
	%	12.0	28.0	9.5	49.6
Very necessary	Observed	23	138	40	201
	Expected	43.37	120.5	37.11	201.0
	%	4.8	28.6	8.3	41.7
Total	Observed	104	289	89	482
	Expected	104.00	289.0	89.00	482.0
	%	21.6	60.0	18.5	100
χ^2 Tests	**Value**	**df**	***p***		
χ^2	41.4	4	<0.001		
N	482				
Gamma	**SE**	**Lower**	**Upper**		
0.327	0.0682	0.193	0.460		
	95% Confidence Intervals				

The chi-square test ($\chi^2 = 42.3$, $p < 0.001$) shows a significant association between these variables, suggesting that the frequency of smart tool usage in personal life is related to the perception of the necessity of AI tools integration from the outset of teacher training. The moderate positive association is further supported by a Gamma coefficient of 0.327.

These findings highlight the impact of personal technological experiences on educators' perceptions of AI's relevance in teacher training. Increasing the regular use of smart tools could enhance recognition of the need for AI-based tools integration in educational practices.

In summary, the analysis reveals a consistent trend across multiple variables: a majority of educators, including both future and experienced teachers, perceives the integration of AI-based tools from initial teacher training as necessary. Educators who are more engaged with technology—demonstrating greater familiarity, knowledge, and personal usage of smart tools—are significantly more likely to advocate for this integration. This perception holds steady across different levels of professional experience, suggesting widespread recognition of AI's importance in modern education. These findings suggest that enhancing educators' technological competencies and familiarity with AI-based tools is crucial for promoting their effective integration into teacher training programs. Such efforts will ultimately support the evolution of educational practices in the digital age and foster the development of technologically proficient and forward-thinking teachers.

However, while contingency table provides valuable insights into associations, it cannot establish causality. To better understand which factors most strongly influence the perception of AI tools integration, we will employ an ordinal logistic regression model. This method enables us to identify the most predictive variables and quantify their effects on educators' views regarding the necessity of integrating AI-based tools from initial teacher training.

6) Ordinal logistic regression study

a) Model specification

Given the ordinal nature of the dependent variable, ordinal logistic regression was the most appropriate method to examine the factors influencing educators' perceptions of the necessity of integrating AI-based tools from initial teacher training. This test enabled the evaluation of the predictive power of independent variables, offering insights into the factors influencing participants' perceptions. The study included both future and expert teachers. The dependent variable, perception of integration necessity, was measured on an ordinal scale. Independent variables were selected for their potential influence on educators' attitudes towards AI, including interest in emerging technologies, mastery of emerging technologies, familiarity with AI, knowledge of AI tools, and use of AI tools in personal life. This method was selected due to the ordinal nature of the dependent variable and the need to assess the impact of multiple factors on this perception (statistically it is polytomous ordinal). Understanding these influences is crucial for shaping educational strategies and policies related to AI integration in teacher training.

This modeling approach involves several steps to analyze data and assess the relationships between variables.

b) Main hypothesis (H4)

There is a significant positive relationship between teachers' interest in emerging technologies, their mastery of emerging technologies, familiarity with AI, knowledge of AI tools and use of AI tools in their personal lives, and their perception of the necessity to integrate AI-based tools from initial training.

To explore these relationships further, the following sub-hypotheses were tested:

(**H4**)**a**: There is a significant positive relationship between teachers' interest in emerging technologies and their perception of AI-based tools integration.

(**H4**)**b**: There is a significant positive relationship between teachers' mastery of emerging technologies and their perception of AI-based tools integration.

(**H4**)**c**: There is a significant positive relationship between teachers' familiarity with AI and their perception of AI-based tools integration.

(**H4**)**d**: There is a significant positive relationship between teachers' knowledge of AI tools and their perception of AI-based tools integration.

(**H4**)**e**: There is a significant positive relationship between teachers' frequent use of AI-based tools in their personal lives and their perception of AI-based tools integration.

c) Data collection

Data were collected through a survey using a 3-point Likert scale. Ethical approval was obtained, and participants provided informed consent. The collected data were deemed reliable, valid, and representative of the target population, with no missing or contradictory values.

d) Verification of the conditions

- **Linearity of the relationship:**

To assess the linearity of the relationship between the independent and dependent variables on the logistic scale, partial probability plots were employed. The absence of significant curvature in these plots suggested a linear relationship. This finding supports the suitability of logistic regression for modeling the data.

- **Collinearity analysis:**

Collinearity among the independent variables was examined through the calculation of Variance Inflation Factors (VIF) (Table 20). All VIF values were below the critical threshold of 3 (ranging from 1.75 to 2.47). This indicates that there is no problematic multicollinearity present, thereby reinforcing the reliability and validity of the results obtained from the ordinal logistic regression analysis.

Table 20. Collinearity statistics

Independent variables	VIF	Tolerance
K1_LIET	1.75	0.570
K2_LMET	2.47	0.405
K3_FAI	2.39	0.418
K4_KAIT	2.10	0.476
K5_LUSTPL	1.76	0.568

- **Proportionality of Chances:**

To assess the stability of the effects of the independent variables on the dependent variable across all ordinal categories, we conducted an odds ratio analysis (Table 21). The results demonstrate that the independent variables K1_LIET (p = 0.013, Odds ratio = 1.564) and K2_LMET (p = 0.022, Odds ratio = 1.746) are significant predictors of the dependent variable P6_ITG. These variables have odds ratios significantly different from 1, indicating that as their values increase, the likelihood of a more favorable outcome also increases. Conversely, the variables K3_FAI, K4_KAIT, and K5_LUSTPL do not significantly affect the dependent variable, as their p-values exceed 0.05, and their odds ratios are not statistically significant (the confidence intervals include the value 1). This suggests that these variables do not meaningfully alter the odds of achieving a better or worse outcome.

Table 21. Odds ratio

Predictor	Estimate	SE	p	Odds ratio	Lower	Upper
K1_LIET	0.44734	0.180	0.013	1.564	1.101	2.23
K2_LMET	0.55746	0.244	0.022	1.746	1.084	2.82
K3_LFAI	0.10802	0.217	0.619	1.114	0.727	1.71
K4_LKAIT	0.22508	0.187	0.229	1.252	0.868	1.81
K5_LUSTPL	−0.00733	0.189	0.969	0.993	0.685	1.44
95% Confidence Interval						

- **Outliers or influential observations:**

Table 22. Cook's distance

Mean	Median	SD	Min	Max
0.00214	9.31e−4	0.00337	1.48e−7	0.0254

To detect outliers or influential observations in our statistical model, we examined the Cook's Distance coefficients. The analysis reveals that no value exceeds 1, with the maximum value being 0.0254, as presented in Table 22. This indicates a low influence of outliers or influential observations on the model. This finding enhance confidence in the validity and accuracy of the model's results.

- **Model fit:**

The model fit was assessed using the Omnibus Likelihood Ratio Test. In the initial analysis (Table 23, Part 1), which included all variables, K1_LIET and K2_LMET exhibited χ^2 values significantly different from zero, with p-values less than 0.05 ($\chi^2 = 6.23043$, $p = 0.013$) ($\chi^2 = 5.25853$, $p = 0.022$), indicating that these variables contribute significantly to the model fit. Conversely, K3_FAI, K4_KAIT, and K5_LUSTPL did not show a significant contribution, as their p-values exceeded the 0.05 threshold.

In the subsequent analysis (Table 23, Part 2), where K3_FAI, K4_KAIT, and K5_LUSTPL were excluded, K1_LIET and K2_LMET continued to demonstrate significant χ^2 values with p-values less than 0.05 ($\chi^2 = 8.70$, $p = 0.003$) ($\chi^2 = 14.43$, $p < 0.001$), reaffirming their importance in the model fit. This suggests that K1_LIET and K2_LMET are key predictors in explaining the variation of the dependent variable.

The non-significance of K3_FAI, K4_KAIT, and K5_LUSTPL, as indicated by confidence intervals that include the value 1 (refer to Odds Ratio Table 20), further suggests that these variables do not significantly contribute to the prediction of the dependent variable. This supports their exclusion from the model to enhance its relevance and precision, consistent with the results of the Omnibus Likelihood Ratio Tests, which demonstrate improved model fit upon their removal.

Table 23. Part 1 of Omnibus likelihood ratio

Omnibus Likelihood Ratio			
Predictor	**χ^2**	**df**	**p**
K1_LIET	6.23043	1	0.013
K2_LMET	5.25853	1	0.022
K3_LFAI	0.24700	1	0.619
K4_LKAIT	1.44993	1	0.229
K5_LUSTPL	0.00151	1	0.969

- **Data analysis:**

Data Analysis: To test the main research hypothesis, an ordinal logistic regression analysis was conducted. The analysis yielded the following results:

e) Interpretation of the results of the ordinal logistic regression

The analysis of the ordinal logistic regression results reveals key insights regarding the model's fit and the influence of the predictor variables on the perception of the necessity to integrate AI-based tools from initial training.

Table 24. Part 2 of Omnibus likelihood ratio

Omnibus Likelihood Ratio			
Predictor	**χ^2**	**df**	**p**
K1_LIET	8.70	1	0.003
K2_LMET	14.43	1	<0.001

- **Model fit:**

The overall model fit (Table 24), assessed using deviance, AIC, and BIC, produced values of 836, 844, and 860, respectively, indicating an adequate fit. A McFadden R^2 value of 0.0631 suggests a modest fit of the model to the data. The overall significance of the model, as determined by the χ^2 statistic ($\chi^2 = 56.3$, $p < 0.001$), confirms that the model significantly explains the variation in the dependent variable.

- **Impact of predictor variables:**

Individual predictor tests (Table 25) reveal that K1_LIET (Level of interest in emerging technologies) and K2_LMET (Level of mastery of emerging technologies) significantly influence the perception of the need to integrate AI-based tools from initial training, with p-values of 0.003 and < 0.001, respectively. These findings underscore the critical role of these variables regarding perception of AI-based tools integration.

In contrast, K3_FAI, K4_KAIT, and K5_LUSTPL did not show significant effects on the dependent variable, indicating they do not substantially contribute to explaining variations in perceptions.

Table 25. Model fit measures

Model	Deviance	AIC	BIC	R^2McF	χ^2	df	p
1	836	844	860	0.0631	56.3	2	<0.001
					Overall Model Test		

- **Conclusion:**

The results of the ordinal logistic regression (Tables 25, 26 and 27) confirm the importance of K1_LIET and K2_LMET in influencing the perception of the necessity to integrate AI-based tools from initial teacher training. These results align with both hypotheses (H0a and H0b) and reinforce the validity of the conclusions drawn from this analysis. The rigorous verification of the preconditions for applying ordinal logistic regression further supports the reliability of these findings.

Table 26. Omnibus likelihood ratio test

Predictor	χ^2	df	p
K1_LIET	8.70	1	0.003
K2_LMET	14.43	1	<0.001

Table 27. Model coefficients

Predictor	Estimate	Lower	Upper
K1_LIET	0.508	0.170	0.848
K2_LMET	0.753	0.363	1.151

SE	Z	p	Odds ratio	Lower	Upper
0.173	2.94	0.003	1.66	1.19	2.34
0.201	3.75	<0.001	2.12	1.44	3.16
		95% Confidence Interval			

B. Discussion

The present study aimed to explore the perceived necessity of integrating AI-based tools from initial teaching training to lifelong learning. To achieve this objective, we administered a survey to collect quantitative data and employed several analytical methods to interpret the results.

- **Relationships between "KNOWLEDGE" and "PERCEPTION"**

Correlation Analysis, EFA, and CFA were employed to identify relationships between variables, uncover underlying factors, and validate the structure of findings.

The findings reveal a significant positive relationship between the knowledge of AI-based tools and the perception of these tools among both future and experienced teachers [20, 56, 69, 70] (Table 7, Inter-factors correlations = 0.687).

This relationship suggests that:

Enhanced understanding of AI-based tools: Teachers with a deeper knowledge of AI-based tools tend to develop a more positive and accurate perception of these technologies, leading to greater acceptance and enthusiasm for their use in educational settings.

Effective integration from initial training: A solid foundation in AI knowledge, coupled with a positive perception, enables future teachers to effectively assimilate AI concepts and integrate them into their teaching practices. This facilitates the use of intelligent tools to enhance educational outcomes. For experienced teachers, this integration promotes pedagogical innovations, such as personalized learning, adaptive content, and automated formative assessments etc.

Positive impact on learner outcomes: The adoption of AI-based tools by teachers can significantly enhance learner motivation, making the learning process more interactive, engaging, and stimulating. This, in turn, has the potential to improve overall learning outcomes.

Ongoing professional development: Teachers with a strong understanding and positive perception of AI are more likely to stay ahead in educational technology. They continually enhance their digital skills, refine their teaching practices, and are committed to ongoing improvement.

This finding aligns with previous research emphasizing the importance of a positive understanding of AI-based tools and its correlation with increased engagement and utilization of these technologies in educational contexts. A deeper comprehension of AI-based tools facilitates their effective integration from initial teacher training, leading to enhanced learner outcomes through personalized and interactive learning experiences. Furthermore, this understanding promotes ongoing professional development for educators, ensuring they remain proficient and adaptable to advancements in educational technologies.

Moreover, Frequency Analysis was used to examine the distribution of participants' responses, which provided empirical support for our hypotheses (H1) and (H2). Specifically, these analyses demonstrated that both future and experienced teachers with satisfactory knowledge of AI-based tools tend to perceive these tools positively and are motivated to integrate them into their teaching practices from the initial stages of their careers [71–73].

Additionally, contingency tables was used to examine the relationship between educators' knowledge level of AI-based tools and their perception of the necessity of integrating these tools in initial teacher training. The Chi-square test ($\chi^2 = 42.3$, $p < 0.001$) confirmed a statistically significant association, and the Gamma coefficient of 0.389 indicated a moderate positive relationship. This analysis confirmed that educators with greater knowledge of AI-based tools are significantly more likely to advocate for their integration from the outset of their training.

These findings from both the Frequency Analysis and the contingency tables analysis with chi-square test provide robust empirical support for hypotheses H1 and H2, highlighting the importance of enhancing AI literacy among educators. This will help strengthen their perceptions of the necessity of early integration of AI tools in teacher training.

Furthermore, the results indicate that both future and experienced teachers exhibit a strong interest in AI and emerging technologies, with a high level of mastery observed among participants. Most are sufficiently familiar with AI, reflecting a growing awareness of this evolving field. While nearly half of the respondents possess moderate knowledge of AI-based tools in teaching, over a third have an in-depth understanding. The frequent use of intelligent tools in personal contexts suggests a readiness among educators to integrate these technologies into their pedagogical practices [72, 74].

The contingency tables with the Chi-square test also provided valuable insights, revealing positive associations between educators' interest in emerging technologies, mastery of these technologies, familiarity with AI, utilization of smart tools in personal life, and their perception of the necessity of integrating these tools from initial teacher training.

Regarding perceptions of AI's role in education, the majority of participants view the use of AI-based tools as essential. Opinions on AI's impact on teaching quality and learning outcomes vary, with some confident in its benefits and others considering it likely. More than half of the respondents believe that AI can ease teaching tasks, potentially allowing educators to focus on more critical aspects of instruction. Additionally, many participants see AI as valuable in addressing cognitive diversity by personalizing learning experiences. Despite AI's potential, the majority affirm that the teacher's role remains crucial, viewing AI as a tool to enhance rather than replace educators [75]. Furthermore, there is strong support for integrating AI into teacher training programs [55, 56].

These findings underscore a widespread interest and recognition of AI's potential among both future and experienced teachers. However, the diversity of opinions on its specific impacts highlights the necessity for comprehensive training and support to effectively integrate AI-based tools into educational practices from initial training [58].

- **Influence of Independent Variables on Perception of AI-based tools Integration from Initial Teacher Training**

The integration of AI-based tools from teacher training is a topic of growing interest and debate within the educational community. This section evaluates the impact of various independent variables—such as years of professional experience, interest in emerging technologies, mastery of emerging technologies, familiarity with AI concepts, knowledge of intelligent tools, and Use of smart tools in personal life —on the perceptions of both future teachers and experienced teachers regarding the necessity of AI-based tools integration from initial training.

Our quantitative analysis, conducted using contingency tables and Chi-Square Tests, which provided further insight into the relationships between variables, reveals a convergence of positive opinions among teachers about the importance of integrating AI-based tools from teacher training programs. This consensus underscores the perceived significance of AI for the future of teacher education [12, 17, 76].

Key findings include:

Years of Professional Experience: Both novice and experienced teachers recognize the importance of integrating AI-based tools from initial training, indicating that professional seniority does not significantly influence this perception.

Interest in Emerging Technologies: Teachers with a strong interest in emerging technologies are more likely to view their integration as essential, suggesting that personal enthusiasm influences professional perceptions

Mastery of Emerging Technologies: A higher level of proficiency with emerging technologies correlates with a stronger perception of the need for their integration, highlighting the importance of developing these skills among future teachers.

Familiarity with AI Concepts: Teachers who are more familiar with AI are more inclined to support its integration from the start of their training, emphasizing the need for increased awareness and education on AI.

Knowledge of Intelligent Tools: Greater knowledge of intelligent tools enhances the perception of their importance in initial training, suggesting that understanding these tools' potential can drive teachers' willingness to adopt them.

Use of Smart Tools in Personal Life: Frequent personal use of intelligent tools is linked to a stronger belief in their necessity for initial training, indicating that personal experience with technology can shape professional attitudes.

As a conclusion, our results highlight the importance of considering various factors influencing the importance of integrating AI-based tools from initial teacher training [15, 59]. These results invite to adapt training programs through the incorporation of AI and its intelligent tools from initial teacher training to prepare teachers for a constantly changing educational environment. These programs could contribute to preparing teachers to meet the challenges of 21st century education and to exploit the potential of emerging technologies to improve the quality of training of future teachers [77, 78].

Our analysis of contingency tables, combined with the Chi-square test, identified significant associations between all independent variables and the perceived necessity for early integration of AI-based tools from teacher training, with the exception of "Years of Professional Experience". The results indicate that educators, regardless of their tenure, hold similarly positive views on the necessity of AI-based tools integration, suggesting that professional experience does not significantly influence their perceptions [20, 57, 79]. Consequently, we reject hypothesis (H3). This finding implies that other factors, such as "Interest in Emerging Technologies", "Mastery of Emerging Technologies", "Familiarity with AI Concepts", "Knowledge of Intelligent Tools" and "Use of Smart Tools in Personal Life", may play a more critical role in educators' perceptions, underscoring the universal appeal of AI integration across different experience levels.

To further explore these relationships and assess the causal impact of each independent variable on the perceived integration requirement, as well as to validate hypothesis (H4), we conducted an ordinal logistic regression analysis. This approach enabled us to identify the most influential predictors of the perceived necessity for AI-based tools integration (Table 28), providing a robust foundation for targeted recommendations and further insights. These recommendations aim to guide stakeholders in recognizing the importance of integrating AI-based tools from the outset of teachers' professional development, thereby supporting more informed and effective integration strategies in initial teacher training programs [14, 60, 75, 76, 80].

Table 28. Summary of the impact of independent variables on perceptions of AI integration

Factor category	Independent Variable	Impact on AI Integration
Technological Proficiency	-Interest in Emerging Technologies -Mastery of Emerging Technologies	Significant Positive Impact
Knowledge and Familiarity	-Familiarity with AI Concepts -Knowledge of Intelligent Tools	No Impact
Personal and Professional Context	-Years of Professional Experience -Use of Smart Tools in Personal Life	No Impact

The ordinal logistic regression analysis revealed that the independent variables "Interest in Emerging Technologies" and "Mastery of Emerging Technologies" as part of the *Technological Proficiency Factor* exert a statistically significant effect on the perception of the necessity to integrate AI-based tools from the initial stages of teacher training. These findings are aligned with our formulated hypotheses, thereby validating sub-hypotheses (H4)a and (H4)b. Specifically, the positive association of these variables suggests that educators who exhibit a higher interest and proficiency in emerging technologies are more inclined to perceive the integration of AI-based tools as crucial from the outset of their professional development.

Conversely, the variables "Familiarity with AI Concepts," "Knowledge of Intelligent Tools," and "Use of Intelligent Tools in Personal Life" did not demonstrate a statistically significant impact on the perception of the necessity for AI tools integration within initial teacher training programs. This indicates that familiarity with AI, Knowledge of Intelligent tools or personal usage of intelligent tools does not necessarily translate into a stronger endorsement of their integration into educational practices from early career stages.

The findings of this study provide valuable insights into the factors that shape educators' perceptions of AI integration in training. The significant influence of interest in and mastery of emerging technologies underscores the critical role that these competencies play in shaping positive perceptions towards AI-based tools. These results suggest that enhancing educators' engagement and proficiency with emerging technologies should be a priority in initial teacher training curricula [81].

To foster a supportive environment for AI integration, it is recommended that initial teacher training programs place a strong emphasis on developing educators' skills and confidence in emerging technologies. Training modules should be designed to not only familiarize future teachers with AI concepts but also to actively cultivate their interest and proficiency in using these technologies. Such targeted interventions could enhance the overall readiness and motivation of educators to adopt AI-based tools in their teaching practices, thereby maximizing the potential benefits of AI integration from the beginning of their careers [53].

In conclusion, this study highlights that while familiarity, Knowledge and personal use of intelligent tools may not independently drive the perceived need for AI integration, interest in and mastery of emerging technologies are key determinants. These findings point to the importance of prioritizing technological skill development in teacher training programs to better prepare educators for the evolving demands of modern educational environments [82, 83].

V. Conclusion

The integration of AI-based tools from initial teacher training is imperative to align with global technological advancements, adapt to the intelligent era, and embrace the Education 4.0 paradigm. This integration is also essential to address the evolving needs of contemporary educational environments.

Our study revealed that educators possess a solid knowledge and a favorable, informed perception of AI-based technologies. Moreover, the findings identified 'Interest in Emerging Technologies' and 'Mastery of Emerging Technologies' as the two most influential predictors of the perceived necessity of integrating AI tools from the inception of teacher training.

These findings underscore the necessity for leaders in initial teacher training programs, particularly within the ENS, to prioritize the integration of AI-based tools into their curricula. Embedding these technologies early in professional development will better prepare educators to effectively utilize AI tools in their teaching practices, thereby enhancing learning outcomes.

The study's promising results also suggest several avenues for further research. Future investigations could focus on evaluating the effectiveness, utility, and potential of AI-based tools as intelligent support systems and virtual tutors. This research could examine their impact on both prospective teachers during initial training and practicing educators in their teaching practices, particularly in pedagogical preparation and the development of multimedia instructional materials. By empirically validating the impact of AI tools, future studies can foster their adoption and integration into educational practices.

AI possesses the transformative potential to revolutionize education by providing personalized, interactive learning experiences. Consequently, it is crucial to equip future teachers with the skills to optimally leverage these technologies, ensuring that the next generation of educators is well prepared to meet the demands of a rapidly evolving educational landscape.

The integration of AI into both initial and in-service teacher education represents a crucial and forward-thinking approach to transforming teaching practices and learning outcomes. This study examined the implications of incorporating AI and its tools from initial teacher training, providing a basis for the following key recommendations aimed at guiding policymakers, educators, and researchers in the effective adoption and strategic use of AI in the educational sector.

- **Emphasize Technological Skill Development:**

Our findings underscore the importance of equipping future educators with robust technological competencies from the outset of their professional training. We recommend integrating AI tools and technologies into teacher education curricula early, enabling future teachers to familiarize themselves with these tools and fostering their readiness to utilize AI in their teaching practices.

- **Promote Early Awareness and Training in AI:**

Stakeholders, including teacher education program leaders, should prioritize raising awareness about the significance of AI and its applications in education. Comprehensive training on AI concepts and ethical considerations should be embedded within teacher education programs to enhance educators' confidence and capability in applying these tools effectively.

- **Adapt Teacher Training Curricula:**

To prepare educators for the dynamic nature of 21st-century education-Education 4.0, it is crucial to adapt training programs by incorporating AI modules and intelligent tools. This curriculum enhancement will support educators in harnessing the potential of emerging technologies, thereby improving the overall quality of teacher preparation.

- **Foster Continuous Professional Development:**

Ongoing professional development opportunities should be provided to current educators, focusing on the effective use of AI tools in educational settings. Continuous learning will ensure that teachers remain adept at utilizing the latest AI technologies, contributing to more innovative and inclusive teaching practices.

- **Facilitate Collaboration and Networking:**

Encouraging collaboration between educators, researchers, and AI professionals will create a vibrant community of practice. This networking can facilitate the sharing of best practices, foster innovation, and drive the effective integration of AI into teaching and learning environments.

- **Support Research and Evaluation:**

Investment in research and evaluation is essential to understand the impact of AI on teaching and learning outcomes. Such efforts will provide valuable insights, guiding future practices and policies for AI integration in education and ensuring that the deployment of AI is evidence-based and targeted towards enhancing educational outcomes.

- **Address Ethical Considerations:**

It is imperative that teachers are equipped to navigate the ethical challenges associated with AI, such as data privacy, security, and algorithmic bias. Training on these aspects will promote the responsible use of AI in educational contexts, safeguarding the integrity and inclusivity of AI-driven solutions.

- **Ensure Adequate Resource Allocation:**

For equitable access to AI tools, it is recommended that resources be allocated to educational institutions for the acquisition, maintenance, and support of AI technologies. This investment will enable all teachers to benefit from the opportunities offered by AI, regardless of their background or the resources of their schools.

- **Advocate for Policy Support:**

To foster the integration of AI in education, advocacy for supportive policies is essential. This includes securing funding for research, infrastructure development, and professional training initiatives. Policy support will provide a sustainable framework for the long-term integration of AI in education.

These recommendations are designed to guide the strategic integration of AI from teacher training programs, enhancing teaching practices. By addressing the needs identified in this study, these recommendations aim to prepare educators to thrive in an increasingly AI-driven educational landscape.

This study offers valuable insights into the factors influencing Moroccan teachers' perceptions, both prospective and experienced, regarding the necessity of integrating AI-based tools from initial teacher training programs. However, several limitations must be acknowledged to contextualize the findings and guide future research.

Firstly, the sample was restricted to teachers from Moroccan public schools within the Fez-Meknes academy and the ENS of Fez. This limitation was primarily due to practical constraints such as financial limitations, logistical challenges, and time restrictions. Consequently, the generalizability of the findings to other institutions or regions within Morocco, as well as to diverse educational systems globally, may be circumscribed. Future research should aim to include a broader and more representative sample from diverse institutions and geographical areas to enhance the external validity of the findings and ensure their applicability across varied educational contexts.

Secondly, the study exclusively relied on quantitative data collected through questionnaires utilizing a three-point Likert scale. While this approach facilitated efficient data collection and analysis, it may have limited the depth of participants' responses and failed to capture the full range of nuanced perspectives and experiences. To address these limitations, future research could incorporate qualitative methods, such as interviews or open-ended survey questions, to enrich the data and provide a more comprehensive understanding of the factors influencing teachers' perceptions regarding the integration of AI-based tools. Additionally, employing a more detailed Likert scale, such as a five- or seven-point scale, could enhance response granularity, offering a deeper and more nuanced analysis of the data.

Moreover, while the analysis focused on predefined variables such as years of teaching experience, interest in emerging technologies, proficiency in new technologies etc, it is important to acknowledge that other potentially influential factors were not explored. Variables such as institutional context, attitudes toward technological change, or specific pedagogical skills could also play a critical role in shaping perceptions. Future studies should consider investigating these additional factors to gain a more in-depth and multifaceted understanding of this critical issue. This would facilitate the refinement of recommendations, leading to a more effective and tailored integration of AI-based tools from initial teacher education programs.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

ML is the main author of this scientific contribution; HF reviewed the draft and contributed to the final manuscript by refining the conception and design; NE provided contributions to the final manuscript. KEK and LA served as the supervisors for this research article. All authors had approved the final version.

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