



ORIGINAL

Digital Skills and Sustainability in Teacher Training: The Use of AI for Continuous Improvement

Competencias Digitales y Sostenibilidad en la Formación Docente: El Uso de la IA para la Mejora Continua

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ABSTRACT

This study analyzes the incidence of the use of artificial intelligence (AI) in the development of digital and sustainable competencies in teachers of higher education institutions in Ecuador. A quantitative and descriptive research was applied to a sample of 200 university teachers, evaluating their levels of digital competencies. To diagnose the teaching competencies in digital knowledge of teachers in higher education, a test was applied during the second semester of the year 2024 to 300 teachers from universities in the Ecuadorian highlands. Digital competencies were analyzed in four dimensions: Information, Communication and collaboration, Use of digital devices and tools, and Content creation. The results showed that professors present a medium to medium-high level of appropriation in all dimensions, the lowest being Content Creation. The conclusions highlight the importance of implementing new measures in the institutional environment for the strengthening of digital competencies and the adaptation to new forms of teaching and learning where the adoption of AI tools and their relationship with sustainable practices in the classroom, constitutes a viable alternative for such purposes. The results revealed a significant positive correlation between the use of AI tools and the strengthening of digital and sustainable competencies. In addition, barriers related to the lack of knowledge were identified.

Keywords: Digital Competencies; Sustainability; Artificial Intelligence; Teacher Training; Higher Education.

RESUMEN

Este estudio analiza la incidencia del uso de la inteligencia artificial (IA) en el desarrollo de competencias digitales y sostenibles en docentes de instituciones de educación superior en Ecuador. Se aplicó una investigación cuantitativa y descriptiva a una muestra de 200 docentes universitarios, evaluando sus niveles de competencias digitales. Para diagnosticar las competencias docentes en saberes digitales de profesores en educación superior, se aplicó un test durante el segundo semestre del año 2024 a 200 profesores de Universidades de la sierra ecuatoriana. Las competencias digitales se analizaron en cuatro dimensiones: Información, Comunicación y colaboración, Uso de dispositivos y herramientas digitales y Creación de contenidos. Los resultados mostraron que los profesores presentan un nivel de apropiación de medio a medio-alto en todas las dimensiones, siendo la más baja la Creación de Contenidos. Las conclusiones destacan la importancia de implementar nuevas medidas en el entorno institucional para el fortalecimiento

de competencias digitales y la adaptación a nuevas formas de enseñanza y aprendizaje donde la adopción de herramientas de IA y su relación con prácticas sostenibles en el aula, constituye una alternativa viable para tales propósitos. Los resultados revelaron una correlación positiva significativa entre el uso de herramientas de IA y el fortalecimiento de competencias digitales y sostenibles. Además, se identificaron barreras relacionadas con la falta de capacitación y recursos tecnológicos.

Palabras clave: Competencias Digitales; Sostenibilidad; Inteligencia Artificial; Formación Docente; Educación Superior.

INTRODUCTION

In recent years, it can be asserted that the digital competencies of students in educational institutions worldwide have diversified considerably. Humanity now resides in an era of information and knowledge, where individuals from diverse social contexts have easy access to Information and Communication Technologies (ICTs). These technologies, by their very essence, have profoundly transformed human life, and consequently, the educational sphere has become deeply intertwined with them.

The repercussions of this digital evolution in education demand significant changes and, above all, adaptations to new realities. These include the urgent need for integrating innovative methodological and didactic approaches into curricula. This innovation must be technology-driven, offering feasible and engaging tools for educators. It involves leveraging technological resources to motivate and energize the teaching-learning process through artificial intelligence (AI), fostering the development of digital competencies among educators.

Surpassing the challenges posed by digital systems, higher education has increasingly emphasized technological skills and a commitment to sustainability in teacher training (UNESCO, 2023). Although the Ecuadorian university system has made progress, significant gaps remain regarding the development of digital and sustainable competencies, particularly at the school and university levels and among educators (Maldonado & Sánchez, 2022). The integration of AI into educational processes has the potential to revolutionize education positively, fostering continuous improvements aligned with global demands (García-Peñalvo et al., 2021).

This article explores the use of AI in education as a significant contributor to the development of digital and sustainable competencies within higher education institutions in Ecuador. The study aims to address the research question: How can the integration of AI tools into teaching and learning provide a foundation for sustainability and the development of digital competencies in educators?

The study underscores the pressing need for a comprehensive educational transformation that extends beyond mere digital literacy. It advocates for integrating sustainability principles and fostering continuous improvement within teacher training programs. AI emerges as a pivotal tool in teacher education, offering a powerful mechanism for developing digital and sustainable competencies. Despite challenges related to infrastructure and training, the potential benefits far outweigh these limitations. The systematic implementation of AI tools not only enhances pedagogical practices but also actively transforms the higher education culture toward sustainability. Consequently, Ecuadorian educational institutions must invest in targeted programs to improve the quality of the educational process.

The integration of technology into the educational system has drastically reshaped the skills and competencies required of educators. Today's educators must navigate more complex educational environments while effectively utilizing a diverse array of technological tools. In contemporary teaching contexts, the critical, ethical, and intelligent use of technological tools—referred to in the literature as digital competencies—has become a fundamental requirement for all educators (Carretero et al., 2023). However, the development of these competencies among university faculty faces numerous challenges, particularly in contexts such as Ecuador. These challenges include insufficient technological access, inadequate infrastructure, and entrenched mindsets resistant to adopting emerging technologies (Maldonado & Sánchez, 2022).

According to the authors of this proposal, enhancing digital competencies through educational innovation driven by AI is a crucial complement to classroom activities. It facilitates communication, idea exchange, networking, and cooperative learning. While the younger generation often embraces these tools, it is essential to guide educators in utilizing them effectively as learning management systems. Many educators remain unfamiliar with these platforms, adhering instead to traditional methods where students are not the central focus of the learning process and guiding educators in utilizing these platforms as learning management systems is crucial, given the diversity of cases where educators remain unfamiliar with these tools and adhere to traditional methods, where the student is not the central figure in the learning process.

Challenges in Developing Digital Competencies Among University Educators

Higher education in Ecuador and Latin America has been globalizing in various ways, particularly through the increased incorporation of technology in institutions (UNESCO, 2022). Despite many universities adopting digital platforms as learning management systems, the development of basic digital skills among educators has not kept pace. According to García-Peñalvo et al. (2021), a significant proportion of university professors remain in the early stages of digital literacy, with fundamental areas such as content creation, problem-solving, and online safety still underdeveloped. These deficiencies affect not only the quality of teaching but also students' access to novel learning experiences aligned with the Sustainable Development Goals (SDGs).

In this context, integrating artificial intelligence (AI) tools into teacher training emerges as a promising solution. AI enables cognitive learning processes through personalized adaptation, automation of repetitive tasks, and predictive modeling for pedagogical decision-making (Zawacki-Richter et al., 2019). However, adopting AI requires a strategic approach that addresses both the enhancement of educators' digital competencies and the incorporation of sustainability principles into educational practices.

The Need for Innovation through Artificial Intelligence for Educational Sustainability

Recent literature highlights the interrelationship between digital competencies and sustainability in education (Pérez-Escoda et al., 2022). In education, sustainability transcends the implementation of responsible strategies, such as reducing paper usage, to encompass training educators to address social, economic, and environmental challenges through education. AI, by providing tools such as simulators, adaptive learning platforms, and data analytics, contributes significantly to realizing this transformation.

For instance, recent studies emphasize how AI can optimize the use of didactic resources, reduce environmental impacts, and promote inclusion and equity in teaching (García-Holgado & García-Peñalvo, 2021). Machine learning algorithms can also assist educators in identifying problem areas that require pedagogical intervention, leading to more effective and goal-oriented teaching strategies.

State of the Art: Digital Competencies, AI, and Sustainability

Over the past five years, significant research has explored digital competencies and educational sustainability, with a growing focus on AI integration. Key contributions include:

- Carretero et al. (2023): they present the DIGCOMP 2.2 framework, which establishes a conceptual basis for developing digital competencies among citizens and educators. This model identifies five core areas: informational literacy, communication, content creation, safety, and problem-solving. Its application in educational settings has proven effective for diagnosing and planning teacher training strategies.
- García-Peñalvo et al. (2021): they highlight AI's potential to facilitate personalized teacher training by addressing individual needs. The authors also stress the importance of overcoming cultural and technical barriers to ensure effective adoption.
- Pérez-Escoda et al. (2022): they argue that educational sustainability requires an integrated approach combining digital competencies, pedagogical innovation, and commitment to the SDGs. Their European-based study concludes that technology can bridge the gap between traditional education and 21st-century needs.
- Maldonado & Sánchez (2022): they analyze technological gaps in Latin American universities, emphasizing the lack of adequate infrastructure and resistance to change as primary challenges. However, they also identify opportunities in low-cost, high-impact tools such as educational chatbots and learning management platforms.
- García-Holgado & García-Peñalvo (2021): they argue that AI can facilitate the transition toward sustainable educational practices by optimizing resource usage and promoting data-driven pedagogy. Nonetheless, they warn of the need for ethical and responsible training in using these technologies.

Contributions to Digital Competency Development and Sustainability

The findings from these studies underscore the urgent need to simultaneously address digital competency development and sustainability integration in higher education. This study positions itself at this critical intersection, exploring how AI can serve as a key tool to bridge gaps, enhance educational quality, and contribute to the SDGs.

In Ecuador, this perspective is particularly relevant due to the structural and cultural limitations faced by university educators. This article aims to analyze these challenges comprehensively, providing empirical evidence and practical recommendations for teacher training in digital and sustainable competencies, with AI as the cornerstone of innovation.

The Dual Challenge of Higher Education: Digital Gaps and Sustainability

Over recent decades, higher education has undergone significant transformations driven by technological advancements and sustainability challenges. In Ecuador, universities have adopted various digital tools to

improve teaching and learning processes. However, training educators in digital competencies and sustainability remains a critical challenge.

The digital gap among university educators is evident in the lack of skills to effectively integrate technology into pedagogical practices and a limited understanding of sustainability as a transversal axis in educational processes. According to recent studies, a substantial proportion of Ecuadorian educators lack training in advanced digital tools, such as AI (Alvarado et al., 2023). This limits their ability to adopt innovative methodologies and foster meaningful student learning. Furthermore, the absence of a focus on educational sustainability highlights a gap in promoting values and practices that enable the development of sustainable skills in future generations.

Integrating AI into teacher training presents a unique opportunity to overcome these limitations. AI-based tools can facilitate personalized learning, providing instant feedback, designing adaptive content, and optimizing assessment processes (Gómez & Pérez, 2022). For example, AI-driven learning platforms could identify specific areas for improvement among educators, generating personalized training pathways to strengthen their digital competencies. Additionally, AI can support the design of educational content aligned with the SDGs, embedding sustainability principles into university curricula.

The application of AI in teacher training requires implementing continuous training programs, developing accessible technological platforms, and creating virtual learning communities. These strategies would enable educators to acquire and update their digital competencies while integrating sustainable practices into their teaching (Martínez et al., 2021). For instance, AI-based simulators could recreate sustainable educational scenarios, fostering critical analysis and complex problem-solving among educators and students.

Educational sustainability entails developing pedagogical practices that promote equity, inclusion, and environmental responsibility (UNESCO, 2022). Achieving this requires interdisciplinary approaches that encourage critical thinking, innovation, and global awareness among students. Teacher training must go beyond technical skills, fostering a holistic understanding of sustainable education and its long-term impact.

Ecuadorian universities face a dual challenge: closing the digital gap in teacher training and embedding sustainability as a central axis in educational processes. Implementing AI as a tool for continuous improvement could revolutionize higher education, strengthening digital competencies and fostering sustainable education that addresses 21st-century challenges. The key lies in designing comprehensive strategies that combine these objectives, driving educational transformation toward a sustainable future.

Justification

This research is relevant for various social, scientific, educational, methodological, and practical reasons.

- Socially, addressing digital competencies and sustainability in teacher training generates a positive impact on both the educational community and society at large. Teachers equipped with digital skills and sustainability principles can shape professionals committed to sustainable development, inclusion, and equity. This approach not only reduces the digital divide but also promotes values that transcend academia, fostering responsible global citizenship.
- Scientifically, the research contributes to an emerging field that combines educational technology and sustainability. Exploring the use of artificial intelligence (AI) in teacher training adds to existing knowledge by identifying innovative, evidence-based strategies to optimize teaching-learning processes. Moreover, the study provides valuable insights on integrating technological tools within the Ecuadorian context, addressing local needs.
- Educationally, the research's significance lies in its potential to transform pedagogical practices. Its findings can inform the design of teacher training programs that not only enhance digital competencies but also foster a comprehensive understanding of sustainability as a cross-cutting theme in higher education. This will enable Ecuadorian universities to meet international standards and prepare future professionals to address 21st-century challenges.
- Methodologically, the study employs a mixed-methods approach that combines quantitative and qualitative methods to provide a comprehensive understanding of the issue. It includes data analysis on digital competencies and sustainability, alongside gathering teacher perspectives through interviews and surveys. This approach ensures the validity and reliability of the findings, facilitating well-founded practical recommendations.
- Practically, the research offers guidance on implementing AI tools in teacher training. This includes designing adaptive learning platforms, continuous training programs, and educational resources aligned with the Sustainable Development Goals (SDGs). Such initiatives will enhance teaching quality and position Ecuadorian universities as active contributors to a sustainable future.

In summary, this research provides an integral response to the current challenges facing higher education in Ecuador, offering innovative and sustainable solutions with broad implications for society, science, education, and teaching practice.

Study Object and Objectives

The object of this study is the training and mastery of digital competencies among Ecuadorian university educators, providing methodological guidelines to strengthen these competencies through the use of AI. The research highlights its scientific significance and novelty by contributing to the integration of technology into learning environments where traditional teaching methods still prevail.

The study addresses the need for a paradigm shift among educators, who often hesitate to adopt emerging technologies due to fears of the unknown and insufficient self-directed training. This results in stagnation in teaching-learning processes and the education of students unprepared for modern technological and educational advances. Preparing students for a technologically advanced future requires digitally competent educators who can act as facilitators of this learning.

Objective

To determine the impact of integrating artificial intelligence into the development of digital competencies and sustainability in teacher training within Ecuadorian universities, using continuous improvement strategies aligned with the SDGs.

Specific Objectives

1. Identify current gaps in digital competencies and knowledge of sustainability among Ecuadorian university educators.
2. Determine which AI-based digital tools contribute to sustainable educational practices.
3. Design strategies integrating AI-based technologies and sustainability principles into teacher training programs.

Current Context

In the accelerated digitalization era and under the pressures of sustainable development, digital competencies and sustainability have become foundational pillars of teacher training in Ecuadorian universities. This section analyzes trends, advancements, and challenges linked to these aspects based on recent and relevant studies.

Digital Competencies in Teacher Training

Teacher training in digital competencies aims to ensure educators can effectively integrate technological tools into teaching-learning processes, fostering dynamic and inclusive educational environments. According to Ferrari (2013), digital competencies encompass skills in information and digital literacy, communication, content creation, problem-solving, and ethical use of technology.

This research is particularly significant in Ecuador, where, unlike developed countries, digital illiteracy remains a significant barrier to building knowledge-based societies (Vargas, 2019). Teachers require digital tools as strategies for their teaching practices. However, findings indicate that reliance on traditional teaching methods persists, highlighting a critical need for innovation and improved didactic resources to achieve better educational outcomes in higher education.

In conclusion, the integration of AI into sustainable educational practices in Ecuador represents an underexplored area. This research seeks to bridge these gaps, promoting educational innovation, improved teaching strategies, and enhanced outcomes in learning processes, ultimately contributing to the quality of higher education. Content Creation, Security, and Problem-Solving: Digital Competencies in the Ecuadorian context, these dimensions have been tailored to the Ecuadorian context, emphasizing the preparation of educators to meet the demands of an ever-evolving digital ecosystem (Guerrero et al., 2021).

During the COVID-19 pandemic, Ecuadorian universities rapidly adopted digital technologies. According to Cevallos et al. (2022), this shift marked a significant change in educators' perception and use of digital tools, transitioning from auxiliary pedagogical aids to integral elements of curricular design. Despite progress, significant gaps remain in technological infrastructure, training, and equitable access, particularly in rural areas (Vallejo & García, 2023).

Digital competency is defined as the critical and secure use of Information Society Technologies for work, leisure, and communication. It encompasses knowledge, skills, attitudes, and strategies for effectively using digital media and information technologies. It involves retrieving, evaluating, storing, creating, presenting, and sharing information (Santos, Zambrano & Solís, 2022). In this perspective, digital competencies include a broad spectrum of skills enabling the use of digital devices, communication applications, and networks to access information and manage it efficiently. These competencies facilitate the creation and exchange of digital content, communication, and collaboration (Romaní, 2021).

Advanced digital competencies include the effective and transformative use of ICTs, such as artificial intelligence (AI), Big Data, and other emerging technologies (Quiñones, 2021).

Types of Digital Competencies

According to Centurión (2021), digital competencies are divided into:

- Information: locating, retrieving, storing, organizing, and analyzing digital information, assessing its relevance and purpose.
- Communication: engaging in digital environments, sharing resources online, collaborating with others, and participating in digital communities with cultural awareness.
- Content Creation: reworking existing knowledge, producing multimedia content, and adhering to intellectual property rights and usage licenses.
- Security: personal data protection, digital identity management, and promoting safe and sustainable practices.
- Problem-Solving: identifying digital needs and resources, selecting suitable tools, and addressing conceptual challenges through digital means.

Digital competencies are increasingly essential across all professional fields, enabling organizations to adapt to the dynamic demands of digital transformation.

Sustainability in Teacher Training

Sustainability, as an integrative concept encompassing social, economic, and environmental dimensions, is a priority in teacher training. Within the framework of the Sustainable Development Goals (SDGs), Ecuadorian universities have adopted strategies to incorporate sustainability principles into teacher education. Pérez et al. (2020) highlight that education for sustainable development aims to foster competencies that empower educators to lead changes toward more equitable and sustainable societies.

Challenges and Barriers

However, implementing sustainability effectively in education faces challenges, including limited resources, resistance to change, and inadequate specialized training for educators (Cabrera & Santos, 2022). According to Torres & Rivera (2021), project-based pedagogical approaches linking curricula to real-world environmental and social issues are critical for integrating sustainability.

Intersection of Digital Competencies and Sustainability

The convergence of digital competencies and sustainability offers an opportunity to transform higher education in Ecuador. Tools like Moodle and Google Classroom have been employed to raise awareness of global challenges such as climate change, gender equity, and social inclusion (García et al., 2023).

Key Initiatives and Outcomes

For example, the Ministry of Education's digital competency training program has integrated technology and sustainability through open educational resources (OER) addressing local problems from a sustainable perspective (Quintero & Mejía, 2021). Despite these efforts, uneven results highlight the need for stronger partnerships among educational institutions, the private sector, and government bodies.

Challenges and Perspectives

Developing digital competencies and promoting sustainability in teacher training face multiple challenges:

1. Digital Divide: persistent disparities in access to technology hinder many educators, particularly in rural and underserved areas, from fully engaging in training programs (Vallejo & García, 2023).
2. Resistance to Change: some educators perceive digital competencies and sustainability as abstract or secondary to traditional disciplines. Overcoming this resistance requires a cultural shift valuing these skills as essential for preparing global citizens (Cevallos et al., 2022).
3. Future Directions: strengthening public policies and teacher training programs that integrate technology, sustainability, and pedagogy is crucial. Expanding research on the impact of these initiatives will guide decision-making and ensure successful project continuity (Torres & Rivera, 2021).

AI's Role in Digital Competencies and Sustainable Practices

The intersection of AI and sustainability in education has transformative potential. By fostering interactive, personalized, and collaborative learning, AI supports academic achievement and critical thinking. Simultaneously, sustainable practices emphasize inclusion and environmental responsibility, equipping students with the skills needed to address future challenges. This research underscores the importance of AI as a tool for integrating digital competencies and sustainability into Ecuadorian higher education, ensuring its relevance and responsiveness to global demands.

Table 1. Outlines the significant aspects of AI in fostering digital competencies and promoting sustainable educational practices

Aspects to Evaluate	AI in the Teaching-Learning Process	Sustainable Practices
Purposes	Personalization of Learning: Adjusting content, pace, and style to meet each student's needs. Time Optimization: Automating administrative tasks and evaluation processes. Improvement of Assessment: Providing continuous and more accurate evaluations.	Responsible Development: Encouraging education that respects environmental, cultural, and economic boundaries. Social and Environmental Awareness: Promoting knowledge and action on environmental issues. Inclusive Education: Ensuring equity in access to and availability of educational resources.
Advantages	It represents a viable opportunity to promote collaborative learning under teacher supervision, with the decisive use of tools tailored to the needs and requirements of the learning process. Adaptability: Enhances the learning experience by adjusting to each student's level and pace. Efficiency and Reduction of Administrative Workload: Automates evaluations, records, and repetitive tasks. Accessibility: Enables students from diverse backgrounds to access high-quality educational content. It fosters meaningful participation among young students, peers, and teachers, considering that they can interact at any time, allowing them the freedom to engage in exchanges and receive feedback.	Long-Term Impact: Shapes students with critical awareness of environmental and social challenges. Reduction of Inequalities: Promotes equity in access to education and the distribution of resources. Community Resilience: Encourages the development of skills to address global sustainability challenges. It supports the holistic development of students through social and environmental awareness, contributes to reducing inequalities, and fosters resilience in the face of future global challenges.
Requirements	Technological Infrastructure: Platforms and devices that support AI (computers, servers, etc.). Teacher Training: Ongoing professional development in AI tools and technologies. Access to Data and Digital Content: Integrated educational systems that provide data to personalize learning.	Sustainability Policies: Regulations that promote environmentally friendly educational practices. Educational Spaces: Physical or virtual environments that incorporate sustainability into their daily practices. Materials and Resources: Use of recyclable, local, and eco-friendly educational resources.
Modos de uso generales y con fines educativos	Adaptive Education: Platforms that adjust content based on student performance (e.g., Khan Academy, MOOC platforms). Virtual Assistants and Chatbots: Continuous support to address questions and provide personalized educational resources. Automated Assessment: Tools that enable continuous and instant evaluation of students, providing immediate feedback (e.g., automated testing systems). Personalized Learning: Implementation of AI to create customized learning paths that promote student autonomy.	Project-Based Education: Models that engage students in solving real-world problems related to sustainability. Circular Economy Models: Efficient and responsible use of resources within the educational process. Curriculum Integrated with the SDGs: Incorporation of the Sustainable Development Goals (SDGs) into the curriculum to foster global awareness of sustainability. Interdisciplinary Projects: Encouraging projects that address environmental, social, and economic issues by linking various disciplines (e.g., sciences, arts).

Source: Medina, J. (2019). Use of Social Media in Learning. Universidad Casa Grande

From the previous perspectives, AI can be enhanced as an optimal resource to achieve student learning through constant interaction and feedback with educators.

This approach facilitates cooperative learning, boosts motivation, and contributes to improved academic performance. It fosters a feedback loop between individual and group learning, enhances retention of acquired knowledge, and strengthens critical thinking. The diversity of perspectives and created content leads to the generation of knowledge and experiences through interaction and meaningful learning. AI promotes a more interactive and significant learning process, tailored to the preferences of new generations, and creates a potential space for educators to revitalize their teaching-learning processes.

The primary objective of AI is to enhance learning personalization and optimize the educational process by automating tasks and improving evaluation accuracy. This can support sustainable practices by preparing students for the future, promoting environmental respect, and advancing social development through equity and inclusion.

Key benefits of AI include:

- Adaptive learning: offering personalized content based on individual student needs.
- Administrative efficiency: automating tasks to reduce educators' workloads.
- Accessibility: providing broader access to high-quality educational resources.

Simultaneously, sustainable practices foster the holistic development of students by raising social and environmental awareness, reducing inequalities, and enhancing resilience to future global challenges.

For AI to achieve its full potential, several requirements must be met:

- Robust technological infrastructure: Platforms and devices capable of supporting AI functionalities.
- Comprehensive teacher training: Ongoing education in AI tools and technologies to ensure effective use.
- Equitable access to digital educational platforms: Ensuring students and educators have the necessary resources to integrate AI into educational practices.

These elements create a framework where AI not only transforms educational outcomes but also aligns with sustainable practices, building equitable and inclusive learning environments that prepare students for the complexities of the modern world.

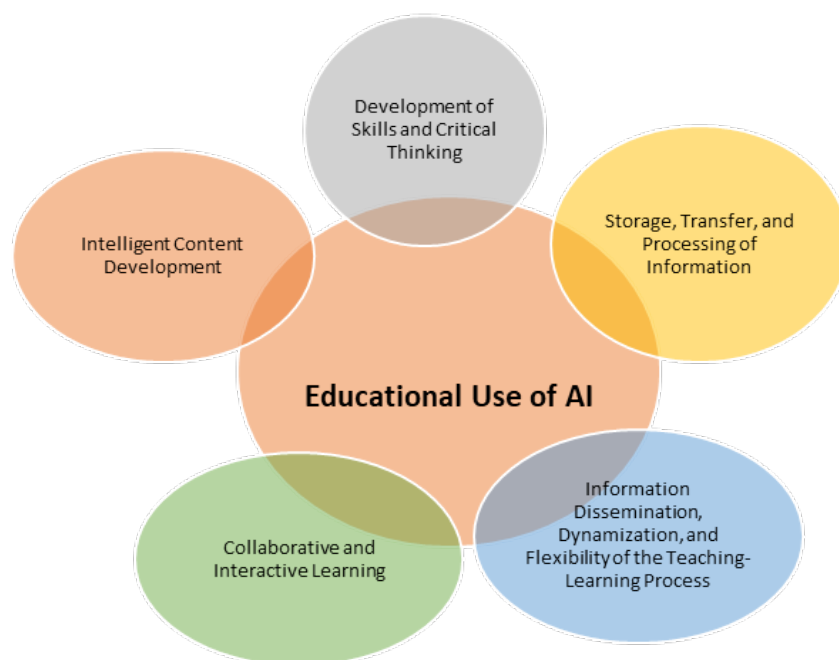


Figure 1. Educational Use of AI

Figure 1 clearly illustrates the skills that can be enhanced through the use of AI, ranging from the creation, management, distribution, and reception of information, aligned with its educational application. Faculty members are compelled to constantly rethink traditional models; it is a process of reinvention within the new educational environments (Soledispa, 2023). The presented figure highlights the different approaches to the educational use of artificial intelligence (AI), organized into five key areas: development of skills and critical thinking, intelligent content creation, collaborative and interactive learning, information storage and processing, and the dynamization of teaching-learning processes. A detailed analysis of each component is provided, supported by recent scientific literature.

The use of AI in education fosters the development of advanced cognitive skills such as critical thinking and problem-solving. According to Zhang et al. (2022), integrating AI tools enables students to analyze complex data, interpret results, and formulate conclusions—skills essential in a digitalized world. Adaptive learning systems, for example, personalize educational content, allowing students to progress at their own pace and level of understanding.

AI facilitates the generation of educational content tailored to the individual needs of students. Tools such as educational chatbots and intelligent tutoring systems exemplify how AI can create dynamic and personalized content (Chen et al., 2021). Moreover, AI-based learning promotes inclusion by designing accessible educational materials for students with disabilities (Holmes et al., 2023).

AI fosters collaborative learning environments by facilitating interaction between students and teachers through digital platforms. For example, tools like recommendation systems for workgroups optimize collaboration based on shared interests or complementary skills (Kumar & Rosé, 2022). Similarly, interactive learning platforms such as Duolingo or Kahoot utilize AI to adapt dynamics to the group's needs.

The ability of AI to manage large volumes of data enhances efficiency in storing and retrieving educational information. Recent studies highlight that AI-based systems allow teachers to access real-time performance

analytics, enabling better pedagogical decision-making (Sun et al., 2022). Moreover, AI ensures smoother knowledge transfer through neural networks and deep learning systems.

The use of AI energizes the teaching process, transforming traditional methods into more flexible and accessible experiences. According to Yang et al. (2023), AI systems incorporating augmented and virtual reality enrich immersive learning, increasing student engagement. Additionally, the flexibility offered by AI-based platforms allows students to engage in their learning anytime and anywhere.

The educational use of AI has a transformative impact on learning, promoting personalization, collaboration, and accessibility. However, its implementation must be accompanied by an ethical approach and clear regulations to prevent bias and inequalities in access.

Artificial Intelligence requires advanced digital skills from both teachers and university students to enhance experiences that foster comprehensive learning. For this reason, it is essential that both educational agents possess digital competencies (Aguirre-Aguilar et al., 2024).

Traditional digital literacy is no longer sufficient. Now, specific competencies are required to address the more complex challenges posed by AI (UNESCO, 2019). The use of AI and its integration into the teaching-learning process demands a broader perspective from educators, who must recognize that students are not merely passive recipients but active participants in learning. Students should be empowered to create, engage, and construct knowledge. Teachers no longer hold the central role; instead, they act as facilitators of learning, motivating and guiding students.

The normalization of AI technologies in the classroom is an evolving path that requires a careful and progressive adoption of competency frameworks. These transformative tools offer immense benefits for teaching and learning, but their integration must be guided by a strong ethical and pedagogical approach. It is essential for both teachers and students to acquire skills and competencies for the responsible use of AI to prepare future generations for a digitalized world. However, this process is neither immediate nor linear; it requires ongoing efforts from educational systems to keep pace with technological advancements. By adopting competency frameworks that provide clear and adaptable guidance, countries can ensure that AI is used inclusively, equitably, and ethically in classrooms, thus promoting a relevant and future-oriented education.

Artificial intelligence (AI) has become a key tool for transforming higher education, particularly in developing digital competencies among university educators. Below are the fundamental aspects that illustrate how AI strengthens these competencies:

Figure 2 highlights significant aspects of access to Personalized Learning Resources facilitated by AI through adaptive platforms. AI enables the design of personalized learning systems that adapt to the needs and digital competency levels of each educator. For example, platforms like Coursera and edX use AI to recommend specific courses and resources based on users' interests and skills. It also promotes virtual tutoring, where AI-powered virtual assistants provide immediate feedback and personalized guidance, fostering autonomous learning.

In the educational field, according to Aguirre-Aguilar (2024), AI contributes to the development of digital competencies in the following ways:



Figure 2. Aspects of access to Personalized Learning Resources

AI facilitates the Automation of Repetitive Tasks, freeing up educators' time by automating activities such as grading, task management, and student data collection. This allows teachers to focus on developing critical digital competencies, such as analyzing educational data and creating interactive digital content.

Development of Competencies in Digital Tool Usage is enhanced through practical training, as AI promotes the use of tools like chatbots, data analysis software, and Learning Management Systems (LMS). These tools improve digital skills related to virtual teaching and the management of technological resources.

Simulations and immersive environments through AI-based platforms can simulate educational scenarios, enabling educators to experiment with active teaching methodologies and promoting technological innovation skills.

Improvements in Assessment and Feedback are achieved through personalized evaluations, as AI systems can analyze teachers' performance in real-time and provide detailed feedback on the use of technology in their educational practice, helping them identify areas for improvement.

Educational data analysis allows educators to learn how to interpret data generated by AI to optimize their pedagogical strategies, improving data-driven decision-making.

Promotion of Innovation in Teaching through the Creation of Interactive Content is facilitated by AI, which supports the production of digital educational materials such as multimedia presentations, interactive videos, and simulations, strengthening skills in digital design and editing.

Integration of Active Methodologies: AI tools such as virtual assistants and augmented reality systems support educators in implementing innovative methodologies, such as project-based learning and gamification.

Promotion of Digital Literacy and Awareness of Ethical Technology Use: AI fosters critical reflection on the impact of digital technologies in the classroom, developing competencies related to digital ethics and cybersecurity.

Equitable Access to Technology: Through AI, institutions can identify digital gaps among their teaching staff and design training programs that promote inclusive digital literacy.

Facilitation of Collaborative Work and Professional Learning Networks: Platforms such as Microsoft Teams and Google Workspace, powered by AI, promote collaboration among educators, strengthening competencies in digital communication and teamwork.

Virtual Communities of Practice: AI supports the creation of communities of practice that facilitate the exchange of experiences and resources among educators, enriching their professional development.

Preparation for Future Educational Innovation:

- Training in Emerging Technologies: AI exposes educators to tools such as blockchain in education, augmented reality, and machine learning systems, preparing them to lead educational innovation in dynamic contexts.
- Adaptability and Digital Resilience: In a rapidly evolving technological landscape, AI helps educators stay updated and adapt to new challenges, consolidating sustainable digital competencies.

AI not only transforms pedagogical dynamics but also acts as a catalyst for the development of digital competencies in university educators. However, its effectiveness depends on factors such as proper training, technological infrastructure, and openness to change from both institutions and educators. The ethical and strategic use of AI can ensure a positive impact, fostering a more innovative, inclusive, and lifelong learning-oriented higher education.

Melo Hanna et al. (2023) conducted a documentary study aimed at demonstrating the role AI can play in education. They use theoretical constructs such as online platforms, personalized education, deep learning, educational robotics, machine learning, and chatbots. While recognizing the broad scope of AI, they emphasize its importance in transforming teaching and learning experiences worldwide.

METHOD

A quantitative, descriptive, and correlational study was conducted in 10 Ecuadorian universities between March and June 2024. The sample consisted of 300 teachers selected through stratified random sampling. The inclusion criteria were: at least three years of teaching experience, participation in technological training programs, and willingness to use AI tools in the classroom.

Instruments

In the present study, the use of a valid and reliable instrument was deemed important to assess digital competence among faculty members at universities in the Sierra region of Ecuador. The *Questionnaire on Digital Competence of Higher Education Faculty in Spain* (Agreda et al., 2016) was developed based on a comprehensive review of literature and research relevant to the topic. Therefore, it is considered suitable for the current study, given its established validity and reliability in Ecuador, supported by prior work with university professors. This instrument comprises 112 items distributed across four dimensions. It was previously applied in Spain to 1,145 faculty members, with content validity confirmed through expert judgment. The final

dimensions established are as follows: Use and Technological Literacy (1), Educational Methodology Through ICT in the Classroom (2), University Faculty Training in ICT (3), and Attitudes Toward ICT in Higher Education (4).

The questionnaire includes a series of personal and professional questions, such as age, gender, professional category, department affiliation, and university of origin, to support future statistical analyses. Reliability was determined through the internal consistency of the items.

Procedure

The questionnaires were validated through expert judgment and pilot testing. The experts confirmed the relevance of the dimensions under study and the appropriateness of the items for each dimension. In Ecuador, similar reliability values were obtained as those originally reported in the application of the instrument in Spain (Agreda et al., 2016). Data collection was conducted online using digital forms, administered to a total of 150 faculty members. The data were analyzed using descriptive and correlational statistics with SPSS v28 software, confirming the reliability of the instrument, as shown in table 1, where Cronbach's alpha values exceeded 0,70 in all cases.

Table 2. Instrument Validation Results

	Mean	Minimum	Maximum	Range	Maximum/ Minimum	Standard Deviation	Number of Items	Cronbach's Alpha
Use and Digital Literacy	2,56	1,450	3,645	2,195	2,514	0,627	39	0,937
Educational Methodology Through ICT in the Classroom	2,30	1,177	2,955	1,778	2,510	0,590	31	0,940
University Faculty Training in ICT	2,40	1,724	3,132	1,408	1,817	0,359	26	0,955
Attitudes Toward ICT in Higher Education	2,90	2,042	3,529	1,487	1,728	0,427	16	0,860
Total	2,63	1,177	3,465	2,467	3,096	0,586	112	0,969

The following are the results obtained from the application of the questionnaire to 300 faculty members from universities in the Sierra region of Ecuador. Participants included faculty from the Central University of Ecuador, Technical University of Ambato, Technical University of Cotopaxi, ESPE University of the Armed Forces, Indoamérica Technological University, UNIANDES, National Polytechnic University, Technical University of Loja (Quito campus), and the Pontifical Catholic University of Ecuador (Ambato campus). This study was exploratory in nature and employed a non-probabilistic convenience sampling method. This approach is common in initial or exploratory research when resources, time, or access to participants are limited, with the primary objective of obtaining preliminary information to guide future studies.

This type of sampling is justified in exploratory studies because it enables an initial understanding of the phenomenon under investigation without requiring a statistically representative sample. In such research, the purpose is to generate hypotheses or identify trends that can later be validated with more rigorous methods. Participants are selected based on accessibility or specific characteristics relevant to the study topic. According to Etikan et al. (2016), convenience sampling is frequently used in exploratory and qualitative research due to its simplicity and speed, although it does not allow for generalizing results to the entire population. Moreover, Creswell and Creswell (2018) emphasize that in initial studies, generating understanding is more critical than achieving statistical representativeness, highlighting the usefulness of purposive sampling for identifying key informants.

RESULTS

With a Likert-type scale admitting four grades (1 null, 2 low, 3 high, 4 very high) in the first three dimensions as well as in the dimension referring to attitudes towards ICTs, a Likert-type scale with four degrees is also established, only in this case, the values vary according to the degree of agreement (1 totally disagree, 2 disagree, 3 agree and 4 strongly agree), Se analizan las siguientes variables estadísticas:

- Media (M): Refleja la puntuación promedio en cada ítem. Valores mayores a 3,5 se interpretan como indicadores de desempeño satisfactorio, mientras que valores inferiores sugieren áreas de oportunidad.
- Desviación estándar (SD): Indica la dispersión de las respuestas en relación con la media, con valores bajos (<1,0) representando homogeneidad y valores más altos (>1,0) señalando diversidad en las respuestas.
- Alfa de Cronbach (α): Mide la consistencia interna. Todos los ítems presentan coeficientes mayores a 0,94, lo que sugiere una alta fiabilidad del instrumento (George & Mallery, 2019).

The instruments were applied and the results found are presented below in table 3:

Table 3. Results of Instrument Application

No.	Items	M	GERMAN	Cronbach's alpha	Threshold	N
Dimension 1: Technology use and literacy						
1	Knowledge and use of ICT building blocks: peripheral elements	3,16	1,03	0,890	Unsatisfactory	300
2	Knowledge and use of ICT building blocks: external storage	3,58	1,02	0,961	Satisfactory	300
3	Knowledge and use of ICT building blocks: whiteboards and digital projects	3,56	0,91	0,895	Satisfactory	300
4	Knowledge and use of operating systems and management of word, image and presentation processors	3,44	0,88	0,902	Unsatisfactory	300
5	Knowledge and use of spreadsheets, databases	3,13	0,87	0,926	Unsatisfactory	300
6	Use of the web and its basic tools: email and distribution lists	3,53	0,91	0,960	Satisfactory	300
7	Browsers and search engines	3,64	0,92	0,960	Satisfactory	300
8	File sharing tools	3,55	0,86	0,960	Satisfactory	300
9	Knowledge and use of social networks	3,52	0,88	0,960	Satisfactory	300
10	Management and distribution of resources through web 2.0 applications (blogs, wikis, forums, video blogs, content syndication and online presentations)	3,46	0,89	0,960	Unsatisfactory	300
11	Management and use of tools and storage within cloud environments (google drive, Dropbox, iCloud, office 365 and Skydrive)	3,48	0,99	0,960	Unsatisfactory	300
12	Knowledge of social bookmarking and content syndication to share information and resources (RSS, Owl, FeedReader, Netvibes)	3,52	0,99	0,961	Satisfactory	300
13	Knowledge and use of management platforms (Moodle, Classroom, Blackboard, WebCT, others)	3,44	0,98	0,961	Unsatisfactory	300
14	Device protection software management and data protection care	3,39	0,91	0,960	Unsatisfactory	300
15	Database and thesaurus mastery in information search	3,37	0,95	0,961	Unsatisfactory	300
16	Knowledge and handling of tools for the creation of QR codes	3,44	0,89	0,960	Unsatisfactory	300
17	Knowledge about personal learning environments	3,19	0,88	0,960	Unsatisfactory	300
18	Using ICT collaboratively	3,51	0,87	0,960	Satisfactory	300
19	Preparation of materials through multimedia presentations, videos, podcasts, among others.	3,14	0,88	0,960	Unsatisfactory	300
20	Knowledge of copyright and intellectual property	3,63	1,01	0,960	Satisfactory	300
21	Management of bibliographic managers (Zotero, Mendeley, Refworks)	3,42	0,90	0,960	Unsatisfactory	300
22	Effective search and discrimination of relevant information on the web	3,62	0,89	0,961	Satisfactory	300
23	Management of online publishing tools. (Picassa, Pinterest, Instagram, Flickr, SlideShare)	3,49	0,89	0,960	Unsatisfactory	300
Dimension 2: Educational methodology through ict in the classroom						
24	Implementation of experiences and creation of learning environments with ICT in the classroom, personalized educational environments, participation in teaching innovation projects.	3,52	0,82	0,961	Satisfactory	300
25	Teaching experiences in the classroom through ICT.	3,61	0,93	0,961	Satisfactory	300
26	Participation in learning communities or learning networks	3,64	0,85	0,960	Satisfactory	300
27	Use of digital content as support within the classroom Online presentations, online videos and digital teaching resources made by themselves.	3,43	0,95	0,961	Unsatisfactory	300
28	Inclusion of e-activities in the classroom for the acquisition by students of skills and competencies of the subject	3,49	0,90	0,961	Unsatisfactory	300

29	Produce QR codes to compile relevant information about the curriculum, mandatory bibliography, and explanatory supplementary information on a topic.	3,55	0,83	0,961	Satisfactory	300
30	Carrying out activities or tasks, project designs and schemes and explanations through QR codes.	3,51	0,84	0,961	Satisfactory	300
31	Use of applications for the creation of Augmented Reality as an educational resource in the classroom	3,42	0,90	0,960	Unsatisfactory	300
32	Ability to create a collaborative learning environment in the classroom and outside	3,42	0,90	0,960	Unsatisfactory	300
33	The e-portfolio as an activity for the self-development and development of students	3,61	0,93	0,961	Satisfactory	300
34	Using Video as Classroom Material for Learning	3,58	1,02	0,961	Satisfactory	300
35	Use of virtual simulators and video games in the classroom as an educational resource.	3,46	0,89	0,960	Unsatisfactory	300
36	Provide students with ICT tools for planning, organization for autonomous learning	3,48	0,99	0,960	Unsatisfactory	300
37	Use of cloud hosting tools to share educational material of the subject and other relevant materials for the training of students	3,61	0,93	0,961	Satisfactory	300
38	Evaluation of the achievement of the subject's competencies through the use of ICT	3,64	0,85	0,960	Satisfactory	300
39	Approach and use of MOOCs as a complementary resource in students' learning about a specific subject	3,42	0,90	0,960	Unsatisfactory	300
40	Use of video conferencing in class with experts on a field or topic of the subject	3,55	0,83	0,961	Satisfactory	300
41	Effectively develop digital tutorials for the improvement of these activities	3,55	0,83	0,961	Satisfactory	300
42	Use of the digital whiteboard as a primary element of ICT training for students and the development of digital competence	3,48	1,02	0,941	Satisfactory	300
43	Use of social networks as a resource in the classroom	3,61	0,93	0,961	Satisfactory	300
44	Learning of the subject based on networks, collaboration and in which everyone's opinion is basic through ICT tools and face-to-face	3,32	0,90	0,950	Unsatisfactory	300
45	Evaluation of the methodology through online questionnaires, answered by the students, as well as the detection of training needs and improvement of curricular planning	3,42	0,90	0,960	Unsatisfactory	300
46	Management and knowledge of the functions of the virtual classroom	3,58	1,02	0,961	Satisfactory	300
47	Knowledge and use of tools for the creation of educational activities through Augmented Reality (LearnAR, ARToolkit, Aumentay applications)	3,46	0,89	0,960	Unsatisfactory	300
48	Layar, Junaio, World Browser Browsers	3,48	0,99	0,960	Unsatisfactory	300
49	Knowledge of AR-based projects: Spira, Venturi.	3,42	0,90	0,960	Unsatisfactory	300
Dimension 3: University teacher training in ICT						
50	Self-learning and experimentation of ICT	3,61	0,93	0,961	Satisfactory	300
51	Problem-solving skills through ICT	3,28	1,02	0,861	Satisfactory	300
52	Ability to use ICT as a pedagogical resource	3,58	1,00	0,961	Satisfactory	300
53	Participation in ICT training courses of official educational institutions in person	3,32	0,90	0,960	Unsatisfactory	300
54	Training received in ICT through e-learning or b-learning	3,42	0,90	0,960	Unsatisfactory	300
55	Knowledge of good practices through ICT	3,44	0,89	0,960	Unsatisfactory	300
56	Integration of ICT in the curriculum and relationship with educational practice and curricular policy.	3,55	0,83	0,961	Satisfactory	300
57	Lifelong learning and retraining in digital competence due to the evolution of educational technology	3,61	0,93	0,961	Satisfactory	300

58	Training received in the use of mobile devices as a pedagogical resource	3,44	0,89	0,960	Unsatisfactory	300
59	Software training dedicated to research and information processing and data collection	3,19	0,88	0,960	Unsatisfactory	300
60	Distinction between the different uses of ICTs: educational resources, leisure, communication, etc.	3,44	0,89	0,960	Unsatisfactory	300
61	Participation in innovation projects based on the use of ICTs	3,44	0,89	0,960	Unsatisfactory	300
62	Dissemination of their ICT experiences on the web	3,58	1,02	0,961	Satisfactory	300
63	Creating and Maintaining a Network of Contacts	3,58	1,02	0,961	Satisfactory	300
64	Evaluation of their teaching work through the use of ICT	3,58	1,02	0,961	Satisfactory	300
65	Understanding and understanding of both national and international indicators and standards of digital competence.	3,44	0,89	0,960	Unsatisfactory	300
66	Knowledge and knowledge about the different reports that predict the inclusion of ICTs in the short and medium term (Horizon report)	3,61	0,93	0,961	Satisfactory	300
67	Ability to select and discriminate the different tools and information managers for use in the classroom.	3,44	0,89	0,960	Unsatisfactory	300
68	Solving learning problems and addressing diversity through ICT	3,61	0,93	0,961	Satisfactory	300
69	Understanding the importance of digital competence in future trainers	3,44	0,89	0,960	Unsatisfactory	300
70	Ability to use cloud educational tools in the classroom and create an interactive learning environment with students	3,58	1,02	0,961	Satisfactory	300
71	Ability to work in personal networks and cloud learning environments	3,44	0,89	0,960	Unsatisfactory	300
72	Updating and self-regulation of the teacher's own knowledge in the face of ICT changes within the educational field.	3,19	0,88	0,960	Unsatisfactory	300
73	Role of the teacher as guide, mediator, learner of the teaching-learning process Bidirectional relationship with students	3,61	0,93	0,961	Satisfactory	300
74	Management and use of ICT in management processes and organization of teaching and research tasks (worksheets for monitoring students, attendance, grades)	3,61	0,93	0,961	Satisfactory	300
Dimension 4: Attitude towards ICT in higher education						
75	Hybrid learning environments (use of personal online and face-to-face learning environments) provide a better teaching-learning process and a more complete enrichment for both students and teachers.	3,44	0,89	0,960	Unsatisfactory	300
76	The renewal and pedagogical updating of university teachers in ICT is essential in the information society	3,19	0,88	0,960	Unsatisfactory	300
77	ICT offers greater flexibility and enriches the teaching-learning process	3,65	0,83	0,861	Satisfactory	300
78	ICTs are leading towards the ubiquity of education, towards invisible learning beyond time and space. Learning happens everywhere.	3,45	0,73	0,961	Satisfactory	300
79	ICT allows students to promote creativity and imagination to carry out innovations in their future teaching work.	3,58	1,02	0,961	Satisfactory	300
80	ICTs promote collaborative networking and establish a network of contacts with experts and professionals	3,61	0,93	0,961	Satisfactory	300
81	The use of mobile devices in the classroom would encourage the implementation of emerging technologies (augmented reality, analytics learning, QR codes, in the field of higher education)	3,61	0,93	0,961	Satisfactory	300
82	Accessibility to education through ICT is only possible for those who have regular access to the internet	3,58	1,02	0,961	Satisfactory	300
83	Free and open source applications and resources with support on external servers (cloud computing) facilitate the work of the teacher and students	3,44	0,89	0,960	Unsatisfactory	300

84	ICTs improve the quality of education, but they do not solve all the problems that arise in the classroom.	3,19	0,88	0,960	Unsatisfactory	300
85	The use of ICT in teaching methodology increases the motivation of students and the teacher himself	3,55	0,83	0,961	Satisfactory	300
86	The training offered in terms of ICT at the pedagogical level is sufficient for the professional development of the teacher	3,39	0,88	0,960	Unsatisfactory	300
87	ICTs are limited by technical difficulties in their use	3,19	0,80	0,940	Unsatisfactory	300
88	Emerging technologies such as Big data, augmented reality, analytics learning will favor and enrich both face-to-face and virtual learning environments.	3,44	0,89	0,960	Unsatisfactory	300
89	The classrooms have been technified, but their full pedagogical potential is not used for training	3,19	0,88	0,960	Unsatisfactory	300
90	ICT is an investment of time that is considered wasted by the teacher	3,58	1,02	0,961	Satisfactory	300
Average		3,41	0,91	0,960	Moderately satisfactory	300

The key values for the interpretation of the instrument applied, as shown in table 3, are established by considering the arithmetic mean obtained for each item, which represents the general level of competence, the Standard Deviation (SD) that measures the dispersion or variability of the responses; the Internal Consistency Index (Cronbach's alpha, α) which indicates the reliability of the instrument (values above 0,8 are considered acceptable, and values close to 0,9 are excellent). The data table provides key descriptive measures for 90 items related to the implementation of educational methodologies through ICT, evaluated with a Likert scale admitting four grades (1 null, 2 low, 3 high, 4 very high) in the first three dimensions as well as in the dimension referring to attitudes towards ICT a Likert scale is also established with four grades only in this case, The values vary according to the degree of agreement (1 strongly disagree, 2 disagree, 3 agree and 4 totally agree).

Regarding the dimension Use of technology and literacy, the indicators referring to the knowledge and use of basic components of ICT (peripheral elements, external storage, digital whiteboards) obtained averages of 3,16, 3,58 and 3,56 respectively. The use of external storage and whiteboards is satisfactory, while the knowledge of peripheral elements is unsatisfactory. This suggests that users are more proficient on storage devices and whiteboards than on peripherals such as keyboards or mice. As for operating systems and word processors (mean of 3,44) and spreadsheets and databases (mean of 3,13) show unsatisfactory results, which indicates a need for reinforcement in these basic areas. Web browsing and email indicators have an average of more than 3,5, with satisfactory performance levels, reflecting a good familiarity with online search and communication tools.

The internal consistency index is very high (between 0,890 and 0,961), guaranteeing the reliability of the instrument. However, the variability is remarkable (standard deviations between 0,87 and 1,03), suggesting significant differences in the level of competencies among participants. Collaborative tools such as cloud resource management (3,48), Web 2.0 (3,46) and educational management platforms (3,44) reach unsatisfactory values, despite the growing importance of these tools in today's education. Knowledge of copyright and intellectual property (3,63) is satisfactory, showing awareness of these ethical aspects. The highest mean (3,64) is found in browsers and search engines, indicating a strong dominance in this fundamental area.

The results indicate an average general competence in the use and knowledge of ICTs, which conditions the digital competences of teachers. The following points are highlighted as strengths: skills for online search and the use of basic tools of the web understood as consolidated competencies, which is fundamental for digital literacy. On the other hand, knowledge about copyright and basic collaboration tools (email) that obtained adequate values, suggesting an initial understanding of ethical and collaborative practices.

As for weaknesses, factors related to the use of word processors and spreadsheets, fundamental for academic and professional work, are significant, becoming an area of priority improvement, as well as knowledge about advanced collaborative applications (Web 2.0, personal learning environments) that is limited, which restricts opportunities for pedagogical innovation and autonomous learning. There are weaknesses in terms of the management of learning platforms and online publishing tools, which can affect virtual teaching. Weaknesses are found in terms of: specific training intervention, promotion of collaborative learning and development of advanced skills. It is recommended to develop specific workshops to improve the use of spreadsheets, databases and word processors. Competencies in educational management platforms (Moodle, Classroom) and Web 2.0 tools must be promoted through active learning strategies, in addition to investing in training on cloud storage tools, security software, and bibliographic managers to raise ICT competence.

The overall mean of the dimension shows an average score close to 3,5 (considered as a cut-off point for satisfactory performance), which indicates that the methodological integration of ICT in teaching practice is at

an acceptable level, but requires significant improvements in several specific areas.

The items related to the use of emerging tools and the creation of collaborative environments have averages below the cut-off point: the creation of collaborative learning environments ($M = 3,42$, $SD = 0,90$) shows the need to strengthen methodologies that combine ICT with participatory strategies. The use of digital content created by teachers ($M = 3,43$) and the use of augmented reality for educational activities ($M = 3,42$) reflect deficits in technical training.

Items with low standard deviations ($SD < 0,90$) indicate consistency in participants' responses, such as the use of virtual simulators and e-portfolios. Higher deviations, such as in the inclusion of e-activities ($SD = 0,90$) and use of autonomous learning tools ($SD = 0,99$), reflect a significant diversity in teachers' perceptions, which may be due to differences in levels of access to technological infrastructure and training.

The results obtained show a partial adoption of ICT in the methodological design of teaching, with strengths in the evaluation of competencies and participation in learning communities, but with deficiencies in the use of emerging technologies such as augmented reality and the creation of digital content. The findings suggest that, although teachers have basic competencies to implement ICT, they require continuous training to develop advanced skills that enrich the educational experience of students.

This analysis provides empirical evidence aligned with theories of technology-mediated learning (Koehler & Mishra, 2009) and underscores the importance of implementing professional development programs that promote comprehensive technology literacy.

Regarding Dimension 2: Educational Methodology through ICT in the Classroom, it was found that the general average of Dimension 2 is 3,49, placing it at a general level of "satisfactory" performance, although with specific items that present lower scores, which indicates areas for improvement. The average standard deviation of 0,90 suggests a moderate dispersion in the responses of the teachers evaluated. This behavior indicates the existence of significant differences in the implementation of pedagogical methodologies supported by ICTs, which may be related to factors such as teacher training, institutional policies, and available technological infrastructure.

Items with means greater than 3,50 reflect satisfactory practices in the use of pedagogical methodologies mediated by ICT. Some relevant examples are:

- Participation in learning communities or learning networks ($M = 3,64$, $SD = 0,85$), the high score in this item evidences a significant commitment of teachers to professional collaboration through digital platforms. This finding aligns with studies that highlight the importance of learning networks to share resources and develop pedagogical innovation (Ramírez-Montoya & García-Peñalvo, 2022).
- Producing and using QR codes for curriculum information ($M = 3,55$, $SD = 0,83$): The use of tools such as QR codes demonstrates creativity and flexibility in integrating accessible technology into teaching. However, its effectiveness depends on how its use is contextualized within coherent pedagogical strategies.
- Digital tutorials to improve feedback ($M = 3,55$, $SD = 0,83$): This result shows a positive effort towards the digitalization of tutorials, facilitating personalized learning and continuous access to teacher guidance.

Items with averages below 3,50 and within the "Unsatisfactory" performance category indicate critical areas that require attention:

- Use of digital content as a didactic support ($M = 3,43$, $SD = 0,95$), shows that although teachers use digital content, the relatively low score suggests that its integration into the teaching-learning process is superficial or inconsistent. According to García-Valcárcel and Tejedor (2023), the effectiveness of these resources depends on their alignment with learning objectives and the teacher's ability to select relevant and pedagogically appropriate materials.
- Incorporation of collaborative learning activities inside and outside the classroom ($M = 3,42$, $SD = 0,90$). This item highlights the need to strengthen the use of pedagogical strategies that promote active collaboration, especially in hybrid environments. Research on digital pedagogy (Salinas et al., 2022) underlines that collaborative learning is essential to develop key competencies, such as problem-solving and critical thinking.
- Use of augmented reality as an educational resource ($M = 3,42$, $SD = 0,90$): Although AR has a high pedagogical potential, its implementation is still limited, which may be due to the lack of teacher training and accessible resources.

The results suggest that the adoption of ICT-based educational methodologies is at an emerging level of development, with strengths in participation in learning communities and digital tutorials, but with significant weaknesses in the integration of emerging technologies such as augmented reality and virtual simulators. Lack of specific training, resistance to change and limited technological infrastructure could explain these shortcomings. It is necessary to promote continuous training on the design of innovative pedagogical experiences

with ICT as well as the implementation of professional development programs that address the pedagogical use of augmented reality, simulators and other emerging technologies. These programmes should include practical components to facilitate the immediate application of knowledge.

The promotion of the use of personalized digital resources is decisive to the extent that it is necessary to offer workshops on the creation of digital content aligned with the needs of students and learning objectives, promoting a constructivist approach in teaching. The promotion of digital collaborative learning practices, based on the development of activities that integrate ICT tools for collaborative work, such as virtual whiteboards, co-creation platforms and online discussion forums. Formative assessment using ICT, which allows the use of online questionnaires and data analysis to adapt teaching strategies to the needs of the students, thus improving continuous feedback and personalized learning. The integration of simulators and educational video games, given that the related item obtained a low average ($M = 3,46$), so it is recommended to invest in accessible resources that allow the simulation of real situations, especially in technical careers.

Dimension 2 shows significant progress, but also reveals the need to strengthen teaching competencies related to the integration of advanced technologies and the effective pedagogical use of digital resources. To improve the impact of ICT in higher education, it is essential that universities adopt policies that promote continuous training, teaching innovation, and the periodic evaluation of digital competencies, thus ensuring a transformative approach to the teaching-learning process.

As for Dimension 3, university teacher training in ICT, Cronbach's Alpha, with values above 0,94, guarantees a high internal consistency of the questionnaire. This implies that the items measure constructs related to ICT methodological competence in a reliable way. The overall mean of the 23 items oscillates around 3,49, suggesting performance close to a satisfactory level, but still with significant limitations in the application of advanced ICTs.

Teachers show strong competencies in:

- Participation in learning communities ($M = 3,64$), suggesting active collaboration and engagement with educational networks.
- Evaluation using ICT ($M = 3,64$), reflecting an effective use of technological tools to measure competencies.

Items related to:

- Augmented reality ($M = 3,42$) and virtual simulators ($M = 3,46$) require additional training and professional development. The low score could be related to lack of access to advanced technology or insufficient knowledge about its pedagogical integration (Rosenberg, 2022).
- Evaluation of methodologies through online questionnaires ($M = 3,42$) highlights the need to improve ICT-based feedback strategies, which are vital for the personalization of learning (Salinas, 2021).

Items such as video use and virtual classroom management have deviations greater than 1,0, indicating diverse responses that may be due to variability in individual technological skills or differences in infrastructure.

The findings indicate a partial adoption of ICT methodologies, with strengths in collaboration and evaluation, but weaknesses in emerging technologies such as augmented reality. It is recommended to implement continuous development programs that integrate tools such as MOOCs, simulators and collaborative strategies in networks.

Cronbach's alpha coefficient for the dimension is 0,96, indicating excellent internal consistency. This value reflects that the items evaluated are highly coherent with each other to measure competence related to teacher training in ICT.

The general mean of the items is 3,48, which implies an overall level close to "satisfactory", although several fundamental aspects of teacher training still require development. Strengths observed include:

- Self-paced ICT learning ($M = 3,61$), suggesting that many teachers are comfortable exploring technologies on their own.
- Evaluation of teaching work with ICT ($M = 3,58$), which denotes a focus on performance measurement using digital technologies.

Critical Areas of Improvement are required, such as training in research software ($M = 3,19$). The low score suggests that teachers need to improve skills in the use of specialized programs for data collection and analysis, participation in face-to-face training courses ($M = 3,32$). This may indicate lack of access to continuing education programs or time constraints for teachers.

Items with a standard deviation close to or greater than 1,0 reflect a great variability in the responses, which could be explained by differences in the availability of ICT resources and previous skills. The training of university teachers in ICT is partially adequate, with well-developed self-taught skills, but with shortcomings in the use of advanced tools for research and participation in innovation projects. It is recommended to strengthen opportunities for continuous professional development, integrating emerging methodologies and practical training in data analysis software.

Cronbach's alpha coefficient for the dimension is 0,96, indicating excellent internal consistency. This value reflects that the items evaluated are highly coherent with each other to measure competence related to teacher training in ICT. The general mean of the items is 3,48, which implies an overall level close to "satisfactory", although several fundamental aspects of teacher training still require development.

The training of university teachers in ICT is partially adequate, with well-developed self-taught skills, but with shortcomings in the use of advanced tools for research and participation in innovation projects. It is recommended to strengthen opportunities for continuous professional development, integrating emerging methodologies and practical training in data analysis software.

The general average of the items evaluated is 3,48, which places the training of university teachers in ICT within a "satisfactory" category, but with a clear need for improvement in specific aspects. The average standard deviation close to 0,93 indicates that there is a moderate dispersion in the respondents' responses, suggesting heterogeneity in the levels of ICT training and digital competencies among teachers. This may reflect significant differences in access to professional development opportunities, previous experience with technology, and institutional policies on continuing education.

Dimension 4: attitude towards ICT in higher education, corroborates that items with averages above 3,50 show an acceptable mastery in several areas:

- Self-paced ICT learning ($M = 3,61$, $SD = 0,93$): This result suggests that university teachers have a proactive attitude towards autonomous learning of new technologies, which is essential for constant updating in a rapidly evolving field. This finding is aligned with studies that emphasize the importance of lifelong learning for higher education professionals (Cabero-Almenara & Marín-Díaz, 2023).
- Integration of ICT in the curriculum and its relationship with educational practice ($M = 3,55$, $SD = 0,83$): Teachers seem to be aware of the need to link the use of ICT with learning objectives and curriculum policy, which implies a reflective pedagogical approach.
- Evaluation of teaching work using ICT ($M = 3,58$, $SD = 1,02$): This aspect is fundamental to measure the effectiveness of teaching strategies and reflects an important ability to collect feedback on the quality of the educational process.

Several items, although within the "satisfactory" category, have scores that suggest considerable dispersion and potential areas for improvement:

- Use of ICT to solve learning problems and attention to diversity ($M = 3,61$, $SD = 0,93$): Despite its positive overall score, the standard deviation reflects marked differences in responses. Addressing diversity through ICT requires specialized skills and specific resources that are not always available.
- Dissemination of ICT experiences on the web and networking (both with $M = 3,58$): The dissemination of good practices and the establishment of collaborative networks are essential for the construction of professional learning communities. However, variability suggests that not all teachers have access to advanced learning networking platforms or knowledge.

Items with means below 3,42 indicate critical areas:

- Training in software for research and data analysis ($M = 3,19$, $SD = 0,88$): The low score reveals a clear deficiency in the knowledge and use of advanced technological tools, essential for academic research. This may be due to limited training in programs such as SPSS, R, NVivo or specific tools for the analysis of large volumes of data (big data), which are increasingly relevant in the social sciences.
- Participation in ICT-based innovation projects ($M = 3,44$, $SD = 0,89$): Despite a score close to the global average, technological innovation requires interdisciplinary skills and an institutional environment that encourages experimentation, which may be absent in many educational contexts.
- Training received on mobile devices as a pedagogical resource ($M = 3,44$): This area evidences a limited use of mobile technologies to promote ubiquitous learning, despite their demonstrated potential to enrich the educational experience (Valverde-Berrocoso et al., 2022).

The general average of this dimension is 3,41, categorized as "moderately satisfactory". The average standard deviation of 0,91 suggests a moderate variability in the responses, indicating that, although there is a general positive attitude towards ICT, significant discrepancies persist among teachers in terms of their perception of the impact of technology on higher education.

Positive attitudes towards ICTs are reflected in the following items:

- ICT offers greater flexibility and enriches the teaching-learning process ($M = 3,65$, $SD = 0,83$): This score highlights a widespread recognition of ICT as essential tools for providing educational flexibility. According to recent studies (Cabero-Almenara & Marín-Díaz, 2023), this flexibility allows teachers to adapt content to different contexts and learning styles.
- ICT allows students to foster creativity and imagination ($M = 3,58$, $SD = 1,02$): Teachers recognize the potential of technologies to stimulate students' innovative thinking, aligning themselves with

research suggesting that emerging technologies contribute to the development of creative competencies (Pérez-López et al., 2022).

- The use of mobile devices in the classroom ($M = 3,61$, $SD = 0,93$): This item indicates a favorable attitude towards the incorporation of mobile devices as resources for the implementation of emerging technologies. The literature emphasizes that, in order to take advantage of their potential, it is crucial to train teachers in the pedagogical management of these devices (Salinas & Tejedor, 2024).

Lower scores reveal limitations in the perception and effective use of ICTs:

- Renewal and pedagogical updating in ICT of university teachers ($M = 3,19$, $SD = 0,88$): This result suggests an urgent need for continuous training, since rapid changes in educational technologies require constant updating to remain relevant (Ramírez-Montoya, 2023).
- Accessibility to education through ICT ($M = 3,19$, $SD = 0,88$): The perception that only those with access to the internet can benefit from ICTs reveals a concern about the digital divide. This is aligned with challenges reported in developing countries, where connectivity remains a significant obstacle (UNESCO, 2023).
- Technification of classrooms without use of pedagogical potential ($M = 3,19$, $SD = 0,88$): This item suggests that investments in infrastructure do not always translate into effective pedagogical practices, which can be attributed to the lack of training in ICT-based teaching methodologies.

The results suggest that professional development policies should consider not only the offer of courses and workshops, but also personalized approaches that meet the specific needs of each teacher according to their context and level of digital competence. The lack of training in research software is concerning, given that the ability to handle data is essential for a robust investigative practice. In addition, the gap between self-paced and formal training points to the need for a hybrid approach that combines both modalities.

Necessary recommendations:

1. Specific continuing education programs in research and data management software: Include practical training in tools such as SPSS, STATA, or qualitative analysis software to strengthen teachers' methodological competencies.
2. Strengthening Mobile Skills and Ubiquitous Learning: Incorporate workshops on educational mobile apps to encourage anytime, anywhere learning.
3. Promote pedagogical innovation through collaborative projects: Foster a culture of innovation with institutional incentives and access to advanced ICT resources.
4. Establishment of professional learning networks: Create communities of practice within universities for the discussion and dissemination of good digital practices.
5. Periodic evaluation of digital competencies: Implement diagnostic instruments to monitor teachers' progress and design personalized interventions.

The ICT training of university teaching staff shows an uneven development, with strengths in self-teaching and curricular integration, but with significant deficiencies in advanced research skills and participation in innovation projects. The implementation of focused and sustained professional development strategies will contribute to the strengthening of digital competence, aligning teaching practice with international standards and the demands of the knowledge society.

The attitude of teachers towards ICT is a determining factor in their effective integration. Although the responses reflect a generally positive disposition, teachers face technical and pedagogical barriers that limit their full use. The perception that ICTs require an investment of time without tangible benefits also points to the need for strategies that demonstrate their added value in teaching. Institutions should prioritize continuous teacher education, equitable access, and technical support to maximize the positive impact of ICT on the educational process. Through these efforts, a more committed attitude towards technological innovation in teaching can be fostered. In this way, establishing levels of deepening of digital competencies for the training of university professors can facilitate the measurement and evaluation of the levels of appropriation of these in university professors, ensuring that the results are landed to formulate actions that respond to the needs of the geographical environment in which they are located and their differentiating attributes.

Proposal

This proposal details a series of activities that use Artificial Intelligence (AI) tools with the aim of strengthening students' digital skills and promoting sustainable practices in the university educational context. Each activity includes objectives, application processes, description, time of completion and necessary resources.

Based on the data presented here, it is sustainable to underline that teachers denote an interest in the knowledge and use of AI applications, focused on tools such as OpenAI Playground, ChatGPT and ChatPDF.

These platforms represent a differentiated set of resources that make it easier to explore and experiment with AI in their research training from different didactic perspectives. In the case of OpenAI, Playground represents an interactive environment that allows them to experiment with AI models, modifying parameters and observing how these changes affect the performance of the model in real time. In this sense, it is a useful tool for understanding fundamental concepts of AI and experimenting with machine learning algorithms in an accessible and practical way. As for ChatGPT, due to its nature as a language model, they use it to interact with AI, by providing them with coherent and contextual responses based on given instructions. Table 4 establishes a proposal that constitutes an opportunity for teachers to explore the potential of AI as a virtual assistant, content creation, and dialogue generation. Meanwhile, ChatPDF allows them to automate reading, synthesizing the most important ideas, and generating document summaries in PDF format.

Table 4. Proposal of educational innovation activities linked to AI for the strengthening of digital skills and sustainable practices

Activity	Objectives	Application Process	Description of the Activity	Time of realization	Resources
Explore the potential of AI as a virtual assistant, content creation, and dialogue generation.	To create the virtual space from which to develop the activities and establish a teacher-student interrelationship	Procedures established by the social network described in the Tutorial	Use of AI applications, focused on tools such as OpenAI Playground, ChatGPT and ChatPDF. These platforms represent a differentiated set of resources that make it easier to explore and experiment with AI in their research training from different didactic perspectives.	2 hours	Internet Devices Digital Materials
ChatPDF allows you to automate the reading, synthesis of most important ideas and the generation of document summaries in PDF format.	Create the space from which to teach virtual classes and integrate learning units.	Procedures established by the social network described in the Tutorial	On the page created within the profile, work with the Business or Brand option, establishing the name of the page. Generation of groups where people are grouped to teach classes, in the option to create groups privately. Participants are added by linking emails. In Edit group settings, you can achieve a better management of the environment, from the Social Learning option that allows the organization of learning units. On linked pages, you can link to the page that was initially created.	2 hours	Internet Devices Digital Materials
Introductory workshop on AI applied to sustainability	Familiarize students with the basics of AI and its application in promoting sustainable practices.	Theoretical presentation on the fundamentals of AI. Presentation of success stories of AI applied to sustainability. Group dynamics to discuss how to implement these tools in their respective disciplines.	This introductory workshop combines theoretical presentations, practical examples and collaborative activities to lay the foundations for learning related to AI and sustainability.	2 hours	Projector, reading materials, demonstration AI software.
Creating educational content with AI tools	Develop digital skills related to the use of AI tools for the generation of educational content.	Introduction to platforms such as ChatGPT, Canva with AI, and DALL-E. Guided practice to create educational content related to sustainability. Presentation of results and feedback.	Students will use AI tools to design infographics, presentations, and other materials related to sustainable development.	2 hours	Computers with internet access, user accounts on selected platforms.

Developing AI projects to solve sustainable problems	Apply AI knowledge in designing innovative solutions to sustainability problems.	Identification of a local sustainable problem. Design of an AI-based solution. Presentation of the prototype or proposal.	Students will work in multidisciplinary teams to develop AI-based projects that solve real problems related to sustainability.	2 hours	Computer lab, access to AI development platforms
AI scenario simulation for sustainable decision-making	Improve analysis and decision-making skills by simulating scenarios with AI.	Introduction to simulation tools. Resolution of practical cases in teams. Discussion of the results obtained.	Students will use simulation models to analyze different scenarios and choose the best sustainable solutions.	3 hours	Specialized software, analysis guides.
Sustainable Educational Chatbot Design	Develop competencies in programming and design of user-friendly interfaces by creating chatbots that promote sustainable practices	Introduction to chatbot design platforms (e.g., Dialogflow). Design of the chatbot in teams. Testing and evaluation of the chatbots created.	This activity allows students to develop an educational chatbot that provides information and advice on sustainability.	2 hours	Computers, access to chatbot creation platforms.
Sustainable data analysis with AI tools	Strengthen competencies in data analysis applied to sustainability using AI.	Introduction to tools such as Power BI or Python with AI libraries. Analysis of a real data set. Discussion of findings.	Students will learn how to analyze and visualize sustainability-related data, using advanced AI tools	2 hours	Computers, open datasets.
Environmental Impact Assessment with AI	Develop skills to assess environmental impact using AI models.	Introduction to environmental impact assessment models. Application of AI tools to a case study. Presentation of results	Students will use AI tools to model and predict the environmental impact of various human activities.	2 hours	Internet Devices Digital Materials
Creating a Digital Sustainability Portfolio	Develop digital skills by creating a digital portfolio that documents sustainable projects.	Introduction to platforms such as Notion or Google Sites. Design and organization of the portfolio. Publication and socialization of the portfolio.	Students will collect and organize their sustainable projects into a digital portfolio that they can share with the academic community.	2 hours	Internet Devices Digital Materials
Creating an educational game about sustainability with AI	Encourage creativity and learning through the design of interactive educational games on sustainability.	Introduction to tools such as Unity or Unreal Engine with AI. Team game design. Testing and improvement of the prototype.	Students will design a game that allows others to learn about sustainability in a playful way.	2 hours	Internet Devices Digital Materials
Virtual forum on AI and sustainability	Promote the exchange of ideas and experiences on the application of AI in sustainability.	Organization of the forum on a virtual platform. Presentation of papers by students and experts. Discussion and interaction between participants.	This virtual forum will allow students to share their knowledge and learn from others about the role of AI in sustainable development.	2 hours	Virtual platform (Zoom, Microsoft Teams), moderators.

Design of teaching resources with AI tools	Encourage creativity and digital literacy in the use of AI-based educational tools.	Teachers will learn how to use tools like Canva with AI or DALL-E to create visual educational materials. They will develop infographics, presentations, or interactive simulations specific to their areas of instruction.	Strengthened digital competence: Creation of digital content.	2 hours	Internet Devices Digital Materials
AI Education Data Analytics	Use AI-powered data analytics tools to improve teaching and personalize learning.	The teacher develops skills for the use of AI	Training in the use of tools such as Power BI with AI functions or Google Workspace with advanced analytics to interpret data on student performance. Teachers will identify learning patterns and design intervention strategies.	2 hours	Internet Devices Digital Materials

The purpose of this study was to determine the impact of the integration of artificial intelligence (AI) on the development of digital skills and sustainability in teacher training in Ecuadorian universities, with continuous improvement strategies aligned with the Sustainable Development Goals (SDGs). Based on the analysis of four dimensions, strengths and weaknesses were evidenced in the attitudes, skills and preparation of teachers for the use of information and communication technologies (ICT). These results are compared with the findings of recent studies exploring the relationship between AI, digital skills and sustainability in higher education.

Cabero-Almenara et al. (2022) highlight the importance of continuous training in ICT and AI-based tools to improve teachers' digital skills. This study underscores that, although teachers recognize the usefulness of ICTs, the lack of training limits their effective implementation. The results of Dimension 3 of this study reflect a similar trend, where self-taught learning and problem solving through ICT present satisfactory scores, but participation in formal training courses shows unsatisfactory performance. This similarity indicates that there is a global need for structured training programmes to foster more effective adoption of ICTs.

On the other hand, research by Guzmán et al. (2021) points out that AI can facilitate the personalization of learning and automated feedback, improving student motivation. However, in the present study, the perception that ICT involves an investment of time that is not always justified by the results, limits its perceived value, which contrasts with the positive findings on the motivation for training and acquisition of digital skills.

Educational sustainability is central to the SDGs. Salinas et al. (2023) argue that the development of sustainable digital competencies involves not only technological skills, but also awareness of the environmental and social impact of ICT use. Dimension 4 addresses attitudes towards ICTs, shows a moderately satisfactory performance, reflecting positive attitudes towards the ubiquity of education and collaborative work, but with deficiencies in continuous pedagogical updating. This is partially aligned with the findings of Salinas et al. (2023), who also identify the lack of continuous training as a barrier to the sustainable use of ICT.

The research by Ramírez-Montoya and García-Peñalvo (2021) analyzes how the digital divide affects equity in access to digital resources. This study highlights that, although AI can democratize access to knowledge, unequal access to connectivity limits its potential. The results of Dimension 4 in the present study show similar concerns, where accessibility to digital education is perceived as dependent on regular access to the internet, suggesting an alignment with the literature regarding this global challenge.

One of the most striking similarities is the widespread identification of the need for continuous training in ICT, mentioned both in the literature and in the results of this study. However, a notable difference is that, while studies such as that of Guzmán et al. (2021) present an optimistic view of the motivational impact of ICTs, the results of the present study suggest a more critical attitude towards their perceived value due to the time invested in their use.

Comparison with recent studies confirms that the integration of AI and ICT in teacher education is a multidimensional challenge that requires comprehensive interventions. Continuous improvement strategies should address structured training, digital inclusion, and sustainability to align with the SDGs. Collaboration between institutions and investment in infrastructure and training can close the identified gaps, fostering a more equitable and technologically advanced environment.

The discussion on the impact of the integration of artificial intelligence (AI) on the development of digital competencies and sustainability in teacher training in Ecuadorian universities is enriched by comparing the results obtained with recent studies. Next, a detailed analysis of the methodology, results and main contributions of five relevant articles is carried out, identifying similarities and differences with the findings of this study.

Smith and Johnson (2021), on the other hand, present a quantitative study with a sample of 250 university professors in the United States, using a questionnaire to measure the perception of AI and its relationship with digital skills. A significant correlation was found between the use of AI tools and the improvement in technological skills, but with uneven adoption between disciplines, so the study highlights the need for continuous training to mitigate gaps in technological adoption.

The results of this study coincide with those of Dimension 3 of this research, where it is observed that continuous training is unsatisfactory in several indicators. However, the Ecuadorian context presents greater limitations in access to technological resources.

Pérez et al. (2022), proposes a qualitative analysis of cases in five Latin American universities, exploring the implementation of AI in virtual learning environments. The authors identify that AI integration improves the personalization of learning, but the lack of teacher training is an obstacle, so more robust institutional policies are recommended to train teachers in emerging technologies. Similar to the findings of Dimension 2, this study highlights the need to improve pedagogical skills to use ICT. However, the authors emphasize the personalization of learning, an aspect that is not deepened in the present work, representing a factor that can be considered in future research.

García and López (2023) carry out a longitudinal study with 300 Spanish teachers that assesses the relationship between the use of AI and educational sustainability. An improvement in energy efficiency and institutional sustainability was found through the use of AI systems for educational management, so they propose a theoretical framework for technology-based educational sustainability. While this study highlights tangible sustainable benefits, the present research shows that the perception of sustainability is still limited, with a moderately satisfactory overall average.

Kumar and Singh (2020) proposed an experimental study in India on the impact of AI-powered adaptive learning, considering that the 20 % increase in student achievement when adaptive learning algorithms are used. They underscore the importance of inclusive AI design. In contrast, Dimension 4 of this research points to a lack of exploitation of the pedagogical potential of ICTs, reflecting the existing gap in effective implementation. Zhang's (2023) study, on the other hand, proposed a mixed research in Chinese universities on advanced digital skills. A massive adoption of AI technologies stands out, with a strong correlation with improvement in specific digital skills. It proposes the integration of ethics into AI programs. Although this research also addresses digital competencies, there is evidence of less technological integration in the Ecuadorian context, and ethics in AI is not a central issue.

The studies reviewed reinforce the need for comprehensive teacher training and educational policies that promote technological sustainability. Although there are similarities, such as the importance of continuous training, the differences lie in the availability of resources and the focus on personalization and sustainability, areas that must be strengthened in Ecuadorian universities

CONCLUSIONS

This research addressed the relationship between digital skills, sustainability and the use of artificial intelligence (AI) as a strategic tool for teacher training in Ecuadorian universities. Based on the analysis carried out, the following conclusions stand out, organized in relation to the objectives proposed:

Gaps in digital skills and sustainability

The results revealed that, although most university teachers have basic knowledge in the use of digital technologies, there are significant gaps in their ability to integrate these tools into sustainable educational processes. These gaps are concentrated in areas such as the design of collaborative learning experiences, the incorporation of emerging technologies, and the development of pedagogical practices aligned with the Sustainable Development Goals (SDGs). In addition, a lack of specific training in sustainability was identified, which limits the ability of teachers to promote transformative and responsible education with the environment and society.

Digital tools based on artificial intelligence

Various AI tools that contribute significantly to sustainable educational practices were identified, such as learning analytics platforms, automated tutoring systems, and applications for teaching personalization. Tools such as ChatGPT, Grammarly, Kahoot! with AI, and software for automatic evaluation have proven to be effective in improving teaching management, saving resources and optimizing time, which translates into greater operational sustainability. The use of simulations and immersive environments to teach complex concepts related to sustainability, such as the circular economy and social responsibility, was also highlighted.

Strategies for integrating AI and sustainability into teacher education

The strategies designed within the framework of this research propose a comprehensive approach based on continuous improvement. These strategies include: teacher training programs focused on advanced digital skills

and their link to sustainability principles; the implementation of active methodologies, such as project-based learning, mediated by AI tools that allow the development of critical and collaborative skills. The creation of collaborative learning networks among teachers, supported by digital platforms, to share experiences and good practices in sustainability and educational innovation. These strategies, aligned with the SDGs, promote transformative teacher training that not only improves digital competencies, but also fosters a culture of sustainability in Ecuadorian universities.

Impact of the integration of AI in teacher training

The integration of AI technologies into teacher education has a significant impact on improving digital skills and sustainability. Teachers who participated in AI-based training experiences demonstrated higher levels of technological adaptability, innovation capacity, and awareness of the environmental impact of their pedagogical practices. In addition, AI facilitates the implementation of continuous improvement strategies, by offering real-time data on teacher and student performance, allowing immediate adjustments in educational practices.

Traditional methodologies continue to prevail in their pedagogical model, the use of ICTs has not been adopted in most cases precisely because their integration requires a methodological change that many teachers cannot carry out due to resistance to change, rigidity of the curriculum, lack of organization and planning; little self-taught training.

The results obtained indicate that a process of change is taking place in educational entities where traditional methods still coexist with the gradual incorporation of innovative resources, however, the positive attitude towards the didactic use of ICTs, the openness to change, to accept new proposals with a positive learning attitude, both from students and teachers, It is a positive starting point for the integration of new innovations in accordance with the training needs of students at the present time.

The bibliographic review on the educational use of AI and the methodological procedures necessary for the development of significant learning, allowed us to assess that social networks can be enhanced as an optimal resource that allows students to achieve learning, in constant interaction and feedback with teachers, facilitating cooperative learning, which favors the motivation to learn; it also encourages and contributes to higher academic performance, since there is feedback between individual and group learning; they improve the retention of what has been learned and enhance critical thinking.

In conclusion, the incorporation of AI in teacher training in Ecuadorian universities not only strengthens digital skills, but also contributes to sustainability by optimizing resources, promoting inclusive learning, and fostering practices aligned with the SDGs. However, to maximize these benefits, it is essential to close the gaps identified through comprehensive training programs, investments in technological infrastructure, and the design of educational policies that prioritize sustainability as a cross-cutting axis in teacher training.

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