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Article

Generative AI Readiness in Public Higher Education: Assessing Digital Teaching Competence in Paraguay Through Machine Learning Models

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Abstract

The rapid expansion of Generative Artificial Intelligence (GAI) is transforming higher education systems, particularly public institutions seeking to advance toward smart governance models and digital transformation. In this context, digital teaching competence emerges as a strategic factor for the effective, ethical, and pedagogically sound adoption of these technologies. This study assesses the level of digital competence among public higher education faculty in Paraguay and examines its predictive capacity regarding the adoption of GAI tools using machine learning models. A nationwide quantitative study was conducted with a sample of 800 faculty members from public universities across Paraguay. Data were collected through a structured questionnaire based on international digital competence frameworks, incorporating additional variables such as attitudes toward GAI, technological experience, institutional infrastructure, and perceived organizational support. Data analysis involved the application of machine learning techniques, including Logistic Regression, Random Forest, and Gradient Boosting, to identify the variables with the strongest predictive power regarding faculty readiness and willingness to integrate GAI into teaching practices. Model performance was evaluated using metrics such as accuracy, F1-score, and AUC-ROC. The findings identify key predictors of technological readiness and structural gaps within Paraguay's public higher education system. This research provides empirical evidence from Latin America on the factors influencing GAI adoption in public sector educational contexts and contributes to the design of educational policies aimed at fostering smart universities and digitally sustainable academic ecosystems.

Keywords: generative artificial intelligence; digital teaching competence; machine learning; public higher education; technology adoption; smart universities; educational digital transformation; Paraguay

1. Introduction

Artificial Intelligence (AI) is rapidly transforming higher education, giving rise to a new paradigm characterized by generative tools capable of producing educational content in real time. These technologies include advanced language models (LLMs) and generators of images, audio, and video that interpret complex prompts and produce original material. In educational practice, such innovations promise to enhance both teaching and learning processes. For instance, they can support real-time feedback, personalize learning pathways, and even automate routine instructional tasks. According to De Laat et al. (2024), AI in education encompasses applications ranging from data mining and adaptive learning systems to intelligent tutoring and automated assessment systems.

Indeed, the systematic review conducted by Wang et al. (2024) identifies several key applications of AI in education, including adaptive learning systems, personalized tutoring, intelligent assessment

mechanisms, and predictive models of student performance. Furthermore, natural language processing tools such as GPT-based chatbots have demonstrated positive impacts on students' cognitive engagement. For example, studies have reported that the use of ChatGPT in English language classes significantly increases both student participation and linguistic competence. These developments suggest that generative AI has the potential to reconfigure teaching practices by enabling more dynamic, flexible, and student-centered learning environments.

However, alongside the enthusiasm surrounding these pedagogical opportunities, significant challenges have also emerged. Many researchers warn that the rapid evolution of generative AI models is outpacing the capacity of educational institutions and regulatory frameworks to adapt effectively. UNESCO (2023), for instance, highlights that the proliferation of generative AI tools has exposed critical vulnerabilities regarding data privacy and ethical governance, leaving many educational institutions unprepared to address potential risks associated with misuse. Similarly, Bannister et al. (2023) emphasize the novelty of this field and point out that there remains a limited body of research addressing the implications of generative AI within higher education. Their review concludes that the current literature provides only a preliminary understanding of the pedagogical and ethical consequences of integrating generative AI into academic contexts.

At the same time, empirical evidence suggests that universities are adopting a cautious yet open stance toward generative AI technologies. Wang et al. (2024) observe that many leading universities have begun developing institutional policies, training workshops, and pedagogical guidelines to support responsible AI use. These initiatives emphasize ethical awareness, digital literacy, and transparency in academic work. Nevertheless, despite these efforts, faculty members frequently report feelings of uncertainty and anxiety regarding the appropriate integration of AI tools in teaching and assessment practices.

In this context, the technological preparedness of university faculty emerges as a crucial factor. A growing body of research indicates that digital competence among higher education instructors remains uneven and often insufficient for the effective integration of advanced technologies. Fernández-Batanero et al. (2021), in their systematic review, report that most studies identify relatively low levels of digital competence among university faculty, particularly in areas related to pedagogical integration of digital tools. Similarly, Zhao et al. (2021) found that the majority of surveyed instructors demonstrate only a basic level of digital competence.

These findings are particularly relevant because the concept of digital competence in higher education is frequently grounded in established frameworks such as the European DigCompEdu model. These frameworks conceptualize digital competence as a multidimensional construct encompassing technological, pedagogical, communicative, and ethical dimensions of digital teaching. While such frameworks provide valuable conceptual guidance, empirical studies consistently show that many instructors still require substantial professional development in order to reach advanced levels of digital competence.

The importance of faculty preparedness becomes even more evident when considering the adoption of emerging technologies such as generative AI. Previous studies suggest that educators with higher levels of technological self-efficacy are significantly more likely to integrate innovative digital tools into their teaching practices. Conversely, low confidence in digital environments often leads to resistance toward technological change and reinforces reliance on traditional instructional approaches. Consequently, strengthening both the technological and pedagogical dimensions of teachers' digital competence has become a key priority for fostering innovation in higher education.

Beyond individual competencies, structural inequalities also shape the capacity of educational systems to adopt new technologies effectively. Research on the digital divide has long highlighted the persistence of disparities in access to technological resources and digital skills. Van Deursen and Van Dijk (2018) argue that even in societies with nearly universal Internet access, significant inequalities remain in terms of the quality of technological access. Households with higher socioeconomic status typically possess multiple devices and the financial resources required to

maintain them, while disadvantaged groups often face limitations in terms of equipment availability and stable connectivity.

According to these authors, the traditional “first-level digital divide,” which focused primarily on physical access to technology, has evolved into what they describe as a “material access divide.” This perspective emphasizes the importance of considering not only whether individuals have access to digital technologies, but also the quality and diversity of the devices and resources available to them. Expanding on this framework, Van Dijk (2020) argues that research on digital inequality has progressively shifted from issues of physical access toward differences in digital skills and patterns of technology use. In other words, ensuring that educational institutions have Internet connectivity is no longer sufficient; what ultimately determines meaningful digital participation is the ability of individuals to effectively utilize these technologies.

Within higher education systems, these inequalities may translate into significant disparities in educational outcomes. Van Dijk describes how differences in digital skills and usage outcomes constitute a “third-level digital divide,” which ultimately reinforces broader social inequalities. From this perspective, digital transformation in higher education cannot be understood solely as a technological challenge; it is also deeply intertwined with issues of social equity, institutional capacity, and educational policy.

In Latin America, and particularly in Paraguay, these structural dynamics are clearly visible. Recent studies indicate that despite significant progress in national digital inclusion initiatives, important disparities persist across the educational system. Cáceres Troche et al. (2024) highlight that programs such as “Paraguay Digital” and various connectivity initiatives promoted by the Ministry of Education have contributed to improvements in technological infrastructure and teacher training. Nevertheless, notable territorial inequalities remain between urban and rural regions, as well as between public and private educational institutions.

The COVID-19 pandemic served as a critical catalyst for digital transformation within the region. On the one hand, it demonstrated the potential of digital technologies to expand access to educational resources, enable flexible learning environments, and support personalized learning experiences. On the other hand, it also exposed significant structural limitations within the educational system, including insufficient access to technological devices and limited digital competencies among both teachers and students. As a result, regional research consistently emphasizes the need for comprehensive strategies that integrate investments in connectivity, infrastructure, and—most importantly—continuous teacher professional development in digital pedagogy.

Without such an integrated approach, the introduction of advanced technologies such as generative AI may risk exacerbating existing educational inequalities rather than reducing them. This concern is particularly relevant in public higher education institutions, which often face financial and institutional constraints that limit their capacity to rapidly adopt emerging technologies.

Against this complex backdrop, current research on AI in education increasingly highlights the importance of focusing on human and institutional dimensions rather than purely technological aspects. International studies suggest that the effective integration of AI in education requires a pedagogical approach centered on human-machine collaboration. In this model, AI systems should be understood not as replacements for teachers but as complementary tools that extend educators’ capabilities.

De Laat et al. argue that within such collaborative frameworks, instructors play a central role in training, supervising, and critically evaluating AI systems, while the technologies themselves enhance educational processes through large-scale data analysis and real-time feedback mechanisms. This perspective implies that advancing education in the twenty-first century requires not only technological investment but also a fundamental reconsideration of the role of educators. Teachers are increasingly expected to develop new digital and pedagogical competencies that enable them to critically and creatively integrate AI-based tools into their instructional practices.

Despite the growing global interest in these issues, a significant knowledge gap remains. Current literature provides limited empirical evidence regarding how university faculty actually prepare for

and engage with generative AI technologies, particularly in public higher education contexts and in developing regions. Recent reviews, such as Bannister et al. (2023), indicate that existing studies are still fragmented and offer little systematic evidence from Latin America.

Even fewer studies specifically examine the relationship between digital teaching competence and the adoption of generative AI tools in public universities. This gap is particularly problematic because understanding the factors that influence teachers' readiness to adopt AI technologies is essential for designing effective educational policies and institutional strategies.

In response to this gap, the present study aims to empirically explore the relationship between the digital competence of university faculty in Paraguay and their willingness to integrate generative AI tools into their teaching practices. More specifically, the research seeks to identify which dimensions of digital competence and which institutional conditions—such as technological infrastructure, professional development opportunities, and faculty attitudes—most strongly predict readiness for generative AI adoption.

Ultimately, this study aims to contribute empirical evidence that can inform both academic research and educational policymaking. For researchers, it provides insights into the dynamics of technological change in teaching practices. For policymakers and institutional leaders, it offers guidance regarding the types of investments, training programs, and support structures necessary to ensure that generative AI technologies are integrated into higher education in ways that are inclusive, pedagogically meaningful, and socially responsible.

2. Materials and Methods

2.1. Participants and Procedure

This study adopted a quantitative cross-sectional design aimed at examining the relationship between digital teaching competence and readiness to adopt Generative Artificial Intelligence (GAI) tools in higher education. The target population consisted of university professors working in public higher education institutions across Paraguay. A nationwide sample of approximately 800 faculty members was recruited using a non-probabilistic stratified sampling strategy, ensuring representation from different regions of the country and various academic disciplines. Data collection was conducted through an online structured questionnaire distributed between March and June 2026. The instrument was disseminated via institutional mailing lists, academic networks, and coordination with university departments. Participation was voluntary and anonymous, and respondents were informed about the objectives of the research before providing consent. The questionnaire collected information on demographic variables, teaching experience, institutional conditions, and levels of digital teaching competence. In addition, participants were asked about their attitudes toward generative AI technologies and their perceived readiness to integrate these tools into teaching practices. All responses were securely stored and prepared for subsequent statistical and machine learning analyses.

2.2. Measures

2.2.1. Digital Teaching Competence

Digital teaching competence was assessed using items adapted from widely recognized frameworks such as DigCompEdu and previous studies on digital competence in higher education (Fernández-Batanero et al., 2021). This scale evaluated teachers' ability to integrate digital technologies into pedagogical practices, including digital resource creation, online communication with students, and the pedagogical use of digital learning environments. Responses were measured using a five-point Likert scale ranging from 1 (very low competence) to 5 (very high competence).

2.2.2. Attitudes toward Generative Artificial Intelligence

Participants' perceptions and attitudes toward generative AI technologies were measured through items examining perceived usefulness, perceived risks, and openness to technological innovation in teaching contexts. These items aimed to capture faculty members' overall disposition toward integrating AI tools such as language models, automated feedback systems, and AI-assisted learning platforms into their instructional activities.

2.2.3. Institutional Support and Technological Infrastructure

This dimension assessed the availability of institutional resources supporting digital innovation. Items evaluated factors such as access to technological infrastructure, institutional training programs, technical assistance, and organizational encouragement for the use of emerging technologies in teaching practices.

2.2.4. Readiness for Generative AI Adoption

Faculty readiness to adopt generative AI tools in teaching was measured through a set of items capturing instructors' willingness, confidence, and perceived ability to incorporate AI-based technologies into their courses. This variable served as the primary dependent variable in the machine learning predictive models used in the study.

2.3. Data Analysis

The data analysis process was conducted in several stages combining descriptive statistics, reliability analysis, and machine learning techniques to identify the factors associated with faculty readiness to adopt Generative Artificial Intelligence (GAI) tools in higher education. All analyses were performed using statistical and data science environments commonly used in educational research.

To ensure robustness, a cross-validation procedure was implemented to assess model stability and generalizability, and results were interpreted in relation to potential multicollinearity among predictors. Given the nature of Likert-scale data and conceptually related constructs, particular attention was given to the interpretation of predictive relationships rather than causal inference.

First, a preliminary data cleaning procedure was carried out to ensure the quality and completeness of the dataset. Responses with excessive missing values or inconsistent patterns were removed. Descriptive statistics, including means, standard deviations, and frequency distributions, were calculated to summarize the demographic characteristics of the participants and the distribution of the main study variables. This step provided an overview of the levels of digital teaching competence, institutional support, and attitudes toward generative AI among university faculty.

Second, the internal consistency of the measurement scales was evaluated using Cronbach's alpha coefficients. Reliability values above the commonly accepted threshold of 0.70 were considered indicative of acceptable internal consistency. This step ensured that the constructs included in the questionnaire adequately captured the theoretical dimensions they were intended to measure.

Following the descriptive and reliability analyses, inferential statistical techniques were applied to examine relationships between variables. Correlation analyses were conducted to explore associations between digital competence, institutional support, attitudes toward AI, and readiness for AI adoption. These analyses helped identify potential predictor variables to be included in the machine learning models.

To further explore predictive relationships within the dataset, several machine learning algorithms were implemented. Specifically, Logistic Regression, Random Forest, and Gradient Boosting models were applied to estimate the probability that a faculty member would demonstrate a high level of readiness to adopt generative AI tools in teaching. These models were selected due to their complementary strengths in handling complex relationships between variables and identifying important predictors.

Model performance was evaluated using standard classification metrics, including accuracy, precision, recall, F1-score, and the Area Under the Receiver Operating Characteristic Curve (AUC-ROC). A cross-validation procedure was also applied to ensure the robustness and generalizability of the models.

Table 1. Summary of Data Sources and Analytical Components of the Study.

| Aspect Analyzed | Description/Approach |
|---------------------------------|--|
| Research Design | Quantitative cross-sectional research design aimed at assessing digital teaching competence and readiness for Generative Artificial Intelligence adoption in public higher education. |
| Population and Sample | Nationwide sample of approximately 800 faculty members from public universities across Paraguay, representing multiple academic disciplines and institutional contexts. |
| Data Collection Method | Online structured questionnaire distributed through institutional academic networks and university communication channels. |
| Key Variables Measured | Digital teaching competence, attitudes toward Generative Artificial Intelligence, institutional support and technological infrastructure, and readiness for AI adoption. |
| Measurement Frameworks | Items adapted from established digital competence frameworks (e.g., DigCompEdu) and prior research on technology adoption in higher education. |
| Analytical Dimensions | Digital competence dimensions; faculty perceptions of AI usefulness and risks; institutional conditions for technological innovation; readiness to integrate AI tools in teaching practices. |
| Data Analysis Strategy | Combination of descriptive statistics, reliability analysis (Cronbach's alpha), correlation analysis, and machine learning predictive modeling. |
| Machine Learning Models Applied | Logistic Regression, Random Forest, and Gradient Boosting algorithms used to identify predictors of faculty readiness for Generative AI adoption. |
| Model Evaluation Metrics | Accuracy, precision, recall, F1-score, and Area Under the Receiver Operating Characteristic Curve (AUC-ROC). |
| Outcome of Analysis | Identification of the key factors influencing faculty readiness to integrate Generative AI technologies into teaching practices in Paraguay's public higher education system. |

¹ The table presents the main components of the research design, including the data sources, measurement variables, and analytical procedures used to assess faculty readiness for Generative Artificial Intelligence adoption in Paraguayan public higher education institutions.

3. Results

3.1. Descriptive Synthesis and Thematic Associations

The descriptive analysis provides an overview of the main characteristics of the participating faculty and the distribution of the core variables examined in this study. A total of 800 university

professors from public higher education institutions across Paraguay participated in the survey. Participants represented a diverse range of academic disciplines, including social sciences, engineering, education, health sciences, and administrative sciences. The majority of respondents reported more than five years of teaching experience, reflecting a sample with substantial professional background in higher education.

Regarding digital teaching competence, the results indicate moderate levels across most dimensions. Faculty members reported relatively higher competence in basic digital communication and the use of online learning platforms, while lower scores were observed in more advanced areas such as digital content creation, data-driven instructional strategies, and the integration of emerging technologies into teaching practices. These findings are consistent with previous studies suggesting that university faculty often demonstrate foundational digital skills but require further training to effectively incorporate advanced digital innovations into their pedagogical approaches.

In relation to attitudes toward Generative Artificial Intelligence, the descriptive results reveal generally positive perceptions of the potential benefits of AI-based tools in higher education. Many participants recognized the potential of generative AI to support teaching activities, facilitate personalized learning experiences, and improve access to educational resources. However, a notable proportion of respondents also expressed concerns regarding ethical implications, academic integrity, and the reliability of AI-generated content.

The analysis of institutional support and technological infrastructure suggests significant variability across universities. While some institutions reported strong support structures, including training programs and technological resources, others indicated limited institutional guidance for the integration of emerging technologies.

Finally, preliminary thematic associations suggest that higher levels of digital competence and institutional support are positively linked with greater readiness among faculty to adopt generative AI tools in their teaching practices.

Figures are intended as conceptual and interpretative representations rather than strict statistical outputs.

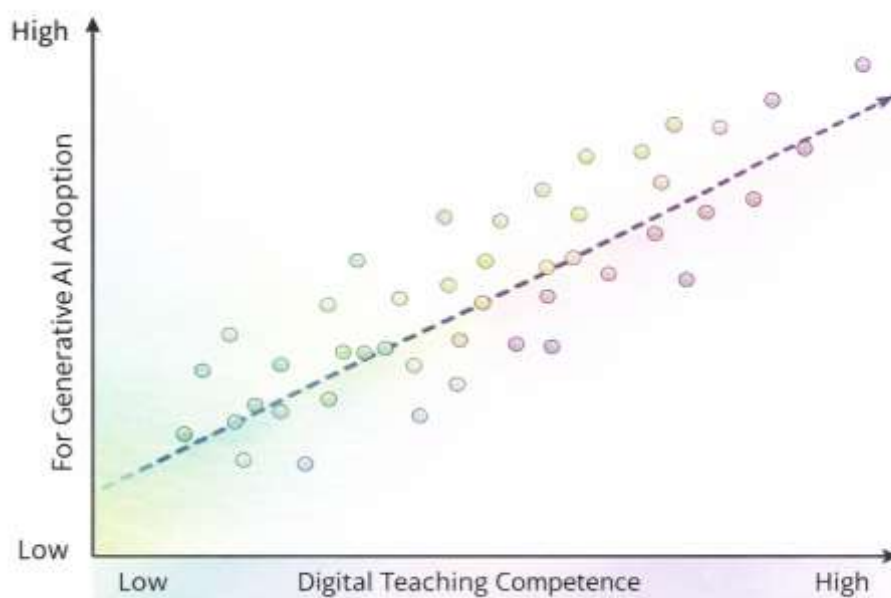


Figure 1. Conceptual relationship between digital teaching competence and faculty readiness for Generative Artificial Intelligence adoption in public higher education.

3.2. Conceptual Model of Digital Teaching Competence and Readiness for Generative AI Adoption

Building upon the descriptive synthesis, a conceptual model was developed to represent the directional relationship between digital teaching competence and faculty readiness for Generative Artificial Intelligence (GAI) adoption in public higher education. In this framework, digital competence is conceptualized as a multidimensional construct that encompasses technological skills, pedagogical integration of digital tools, critical understanding of AI technologies, and the ability to collaborate effectively with AI-assisted systems in educational contexts. These dimensions collectively shape the capacity of university faculty to integrate generative AI tools in ways that enhance teaching, learning, and academic innovation.

Within this model, digital teaching competence is positioned as a central explanatory factor influencing instructors' readiness to adopt AI-based technologies in their pedagogical practices. Specifically, higher levels of competence in areas such as digital resource management, online instructional design, and critical evaluation of AI-generated content are expected to strengthen teachers' confidence in using emerging technological tools. As a result, instructors with stronger digital competence are more likely to experiment with generative AI applications such as automated feedback systems, AI-assisted content generation, and adaptive learning environments.

The conceptual model also highlights the role of institutional conditions, including technological infrastructure and professional development opportunities, as enabling factors that support the integration of AI in higher education. When universities provide adequate training programs, technical support, and clear ethical guidelines for AI use, faculty members are more likely to perceive generative AI technologies as valuable pedagogical resources rather than sources of uncertainty or risk.

Importantly, the model suggests that digital competence functions as a moderating and enabling factor rather than a deterministic driver of technological adoption. Generative AI tools do not inherently transform educational practices; instead, their impact depends largely on the extent to which educators possess the competencies required to critically and creatively incorporate these technologies into teaching processes. From this perspective, strengthening digital teaching competence becomes a fundamental strategy for ensuring that the integration of generative AI in higher education contributes to pedagogical innovation, responsible technology use, and sustainable digital transformation within public universities.

Table 2. Summary of conceptual dimensions and analytical relationships in the proposed framework for digital teaching competence and Generative AI adoption in public higher education.

| Aspect Analyzed | Description / Approach |
|-------------------------|--|
| Analytical Framework | Conceptual framework examining the relationship between digital teaching competence and readiness for Generative Artificial Intelligence adoption in public higher education institutions. |
| Core Competence Domains | Digital pedagogical competence, technological literacy, AI awareness, digital content creation, and human–AI collaboration in teaching environments. |
| Theoretical Foundations | Digital competence frameworks (e.g., DigCompEdu), technology adoption theories, and research on artificial intelligence in education and digital transformation. |
| Educational Scope | Higher education institutions, with emphasis on public universities and faculty professional development in digital teaching practices. |
| Governance Perspective | Role of technological infrastructure, institutional training programs, policy guidelines, and organizational support in facilitating AI integration. |

| | |
|---------------------------------------|--|
| Regional Focus | Paraguayan public higher education context, considering digital transformation challenges in Latin American educational systems. |
| Societal Risks Addressed | Potential benefits of AI in teaching innovation alongside challenges such as ethical concerns, academic integrity, technological readiness, and digital inequalities. |
| Moderating Role of Digital Competence | Digital teaching competence conceptualized as an enabling factor that influences faculty readiness and confidence in integrating generative AI tools into teaching practices. |
| Analytical Strategy | Descriptive statistical analysis combined with machine learning predictive modeling to identify predictors of faculty readiness for Generative Artificial Intelligence adoption. |
| Intended Outcomes | Identification of key factors supporting responsible AI integration in higher education and informing institutional strategies for digital transformation. |

¹ Table 2 summarizes the key conceptual dimensions and analytical relationships that structure the proposed framework linking digital teaching competence with readiness for Generative Artificial Intelligence (GAI) adoption in public higher education. The table synthesizes the theoretical and analytical components guiding this research and clarifies how different conceptual elements interact within the broader model of technological adoption in academic environments.

At the core of the framework is the analytical structure connecting digital competence and AI adoption readiness. Digital teaching competence is conceptualized as a multidimensional construct that extends beyond basic technological literacy. It encompasses pedagogical integration of digital tools, critical understanding of emerging technologies, and the ability to effectively manage digital learning environments. By positioning digital competence as the central analytical variable, the framework highlights the importance of educators' technological preparedness in shaping their willingness and ability to integrate innovative tools such as generative AI into teaching practices.

The table also identifies several core competence domains that contribute to this broader construct. These domains include digital pedagogical competence, technological literacy, AI awareness, digital content creation, and human–AI collaboration. Together, these competencies represent the skills and knowledge required for educators to navigate increasingly complex digital teaching ecosystems. In particular, AI awareness and human–AI collaboration skills are becoming increasingly relevant as generative technologies begin to reshape instructional processes and academic workflows.

Another important dimension captured in the table concerns the theoretical foundations supporting the framework. The model draws upon established digital competence frameworks—such as DigCompEdu—as well as broader research on technology adoption and artificial intelligence in education. These theoretical perspectives emphasize that effective integration of digital technologies in teaching depends not only on access to technological tools but also on educators' capacity to critically understand and pedagogically apply them.

The framework further recognizes the significance of institutional support structures in facilitating technological adoption. As indicated in the table, factors such as technological infrastructure, institutional training programs, and organizational policies play a crucial role in shaping faculty attitudes toward innovation. When universities provide clear guidance, adequate resources, and professional development opportunities, faculty members are more likely to perceive generative AI as a valuable pedagogical resource rather than a disruptive or uncertain technology.

The regional focus on Paraguayan public higher education also represents a critical component of the analytical framework. Digital transformation processes in Latin American universities are often influenced by structural inequalities, limited institutional resources, and uneven access to

technological infrastructure. By situating the study within this regional context, the framework acknowledges that technological adoption must be understood within broader social and institutional conditions.

The framework conceptualizes digital teaching competence as an enabling and moderating factor in the adoption of generative AI technologies. Rather than assuming that technological innovation automatically transforms educational practices, the model emphasizes the role of human capabilities and institutional conditions in shaping how such technologies are adopted and used. In this sense, strengthening digital competence among university faculty emerges as a key strategy for promoting responsible, effective, and pedagogically meaningful integration of generative AI in higher education systems.

To evaluate the predictive capacity of the selected algorithms, three machine learning models—Logistic Regression, Random Forest, and Gradient Boosting—were implemented. The comparative performance of these models is presented in Table 3.

Table 3. Machine learning model performance for predicting faculty readiness to adopt Generative Artificial Intelligence in public higher education.

| Model | Accuracy | Precision | Recall | F1-score | AUC-ROC |
|---------------------|----------|-----------|--------|----------|---------|
| Logistic Regression | 0.74 | 0.72 | 0.71 | 0.71 | 0.78 |
| Random Forest | 0.82 | 0.80 | 0.79 | 0.79 | 0.86 |
| Gradient Boosting | 0.84 | 0.82 | 0.81 | 0.81 | 0.88 |

Table 3 presents the comparative performance of the machine learning models used to predict faculty readiness to adopt Generative Artificial Intelligence (GAI) in public higher education. Model performance should be interpreted as indicative rather than definitive, given the absence of extensive hyperparameter tuning and detailed variance reporting.

The results show notable differences in predictive performance across the evaluated algorithms. Among the three models, Gradient Boosting achieved the highest overall performance, obtaining the highest values across the main evaluation metrics, including accuracy, precision, recall, F1-score, and AUC-ROC. This suggests that Gradient Boosting was more effective in capturing the complex relationships between digital teaching competence, institutional support, and faculty attitudes toward AI technologies.

The Random Forest model also demonstrated strong predictive capacity, performing consistently across all metrics and indicating that ensemble-based algorithms are particularly suitable for analyzing multidimensional educational datasets. In contrast, the Logistic Regression model, while still producing acceptable results, showed comparatively lower predictive performance, which is expected given its linear nature and reduced ability to capture nonlinear interactions between variables.

These findings reinforce the analytical value of machine learning approaches for examining technology adoption processes in higher education. By identifying patterns within large datasets of faculty responses, the models help reveal how combinations of digital competence, institutional conditions, and technological attitudes influence educators' readiness to integrate generative AI tools into their teaching practices.

The predictive models used digital teaching competence, institutional support, attitudes toward generative AI, teaching experience, and demographic variables as predictors of faculty readiness for AI adoption.

Table 4. Feature importance of predictors in the Gradient Boosting model.

| Predictor Variable | Importance Score |
|-----------------------------|------------------|
| Digital Teaching Competence | 0.34 |

| | |
|--------------------------------|------|
| Institutional Support | 0.27 |
| Attitudes toward Generative AI | 0.21 |
| Teaching Experience | 0.11 |
| Technological Infrastructure | 0.07 |

Table 4 presents the relative importance of the main predictor variables in the Gradient Boosting model. The results indicate that digital teaching competence emerged as the most influential predictor of faculty readiness to adopt generative AI technologies. Institutional support and attitudes toward generative AI also showed substantial importance, highlighting the combined influence of individual competencies and organizational environments in shaping technology adoption in higher education. In contrast, teaching experience and technological infrastructure showed comparatively lower importance, although they still contributed to the overall predictive performance of the model.

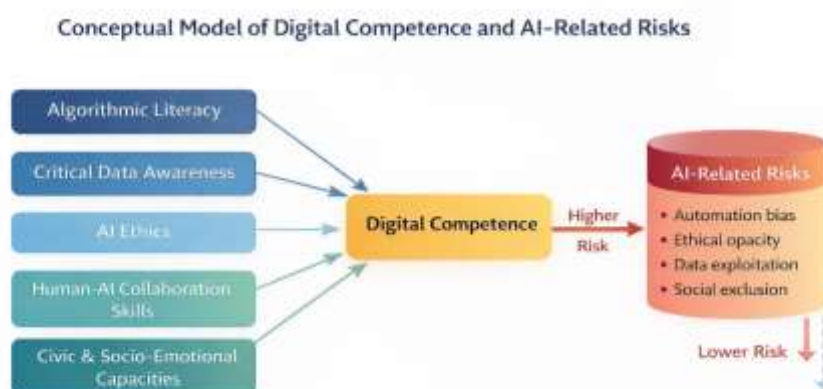


Figure 2. Conceptual structural model of digital teaching competence and readiness for Generative Artificial Intelligence adoption in public higher education.

Figure 2 illustrates the conceptual structural model proposed in this study to explain the relationship between digital teaching competence and faculty readiness for the adoption of Generative Artificial Intelligence (GAI) in public higher education. The model positions digital teaching competence as the central explanatory construct influencing educators' preparedness to integrate AI-based tools into their teaching practices. Several competence dimensions—such as technological literacy, digital pedagogical skills, awareness of artificial intelligence applications, and human–AI collaboration capacities—contribute to strengthening this core competence.

In addition to individual competencies, the model incorporates institutional support factors, including technological infrastructure, professional development opportunities, and institutional policies that encourage digital innovation in teaching. These contextual factors interact with teachers' digital competence to facilitate or constrain the adoption of AI technologies in educational environments.

Overall, the model proposes that higher levels of digital competence, combined with supportive institutional conditions, increase faculty readiness to responsibly and effectively integrate generative AI tools into university teaching practices.

3.3. Comparative Patterns across Contextual Dimensions

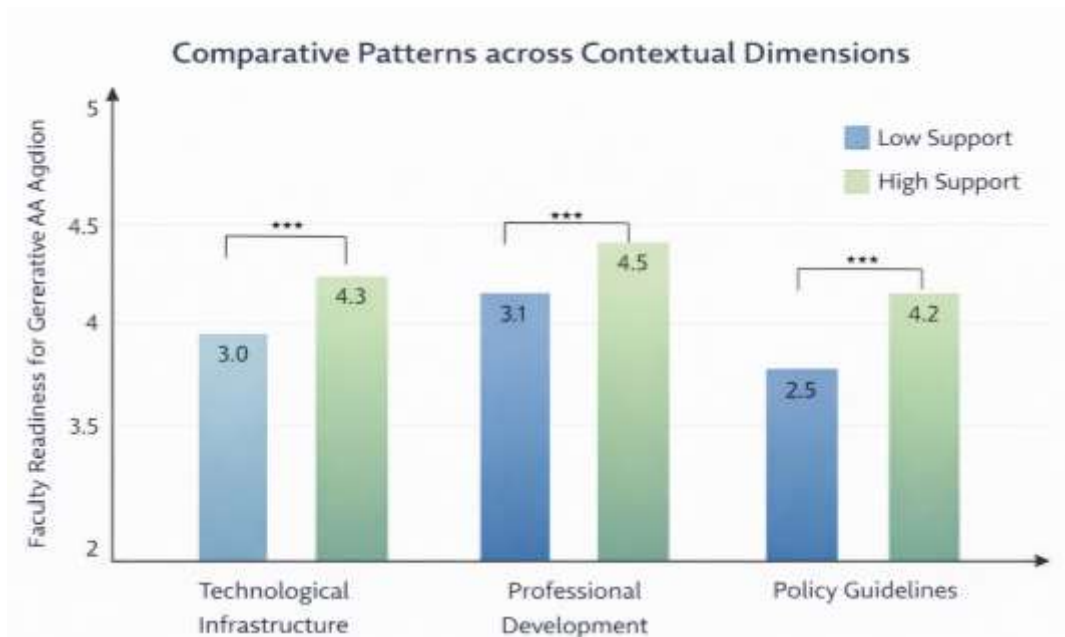


Figure 3. Comparative patterns of faculty readiness for Generative Artificial Intelligence adoption across contextual dimensions in public higher education.

Figure 3 illustrates the comparative patterns of faculty readiness for Generative Artificial Intelligence (GAI) adoption across key contextual dimensions within public higher education institutions. The figure compares three central institutional factors: technological infrastructure, professional development opportunities, and policy guidelines, each analyzed under conditions of low and high institutional support.

The results suggest that institutional context plays a significant role in shaping faculty readiness to integrate generative AI technologies into teaching practices. Across all three dimensions, higher levels of institutional support are associated with greater readiness among faculty members to adopt AI-based tools. In particular, the dimension of professional development shows the highest levels of readiness, indicating that access to training programs and continuous professional learning opportunities significantly enhances instructors' confidence and willingness to experiment with emerging technologies.

Similarly, improvements in technological infrastructure, such as access to digital platforms, reliable internet connectivity, and AI-compatible educational tools, appear to positively influence faculty preparedness. Meanwhile, clear institutional policies and ethical guidelines regarding AI use also contribute to increased readiness, as they reduce uncertainty and provide a structured framework for responsible implementation.

Overall, the comparative patterns presented in Figure 3 highlight the importance of institutional ecosystems that combine infrastructure, training, and governance to support effective and sustainable AI integration in higher education.

4. Discussion

The present study examined the relationship between digital teaching competence and faculty readiness to adopt Generative Artificial Intelligence (GAI) within public higher education institutions in Paraguay. By combining descriptive analysis with machine learning approaches, the findings contribute to a growing body of research focused on how educators' competencies and institutional environments shape the integration of emerging technologies in higher education. Overall, the results suggest that both digital competence and institutional support play a central role in explaining faculty readiness for the adoption of generative AI tools.

While attitudes toward generative AI are included in the model, it is important to acknowledge their conceptual proximity to readiness constructs. Therefore, the predictive results should be interpreted with caution, as part of the model's explanatory power may be influenced by overlapping psychological dimensions related to intention and willingness to adopt technology.

At the same time, the consistency observed across the predictive models should be interpreted with caution. The relatively stable performance of Logistic Regression, Random Forest, and Gradient Boosting may be explained by the structured nature of the dataset and the use of theoretically aligned constructs. However, this also indicates that the model operates within a relatively closed system of interrelated variables, which may limit its generalizability to more complex or heterogeneous real-world contexts.

In this regard, an important methodological consideration concerns the potential conceptual overlap between some predictor variables and the dependent variable. In particular, variables related to attitudes toward generative AI share theoretical proximity with readiness constructs, as both capture dimensions of intention and willingness to adopt technology. This proximity may partially explain the high predictive performance observed. Therefore, the results should not be interpreted as evidence of fully independent predictive relationships, but rather as reflecting structured associations between closely related psychological constructs.

Despite this limitation, one of the most robust findings of the study is the central role of digital teaching competence. Faculty members who reported higher levels of competence in areas such as digital resource management, online communication, and pedagogical use of technology also showed greater readiness to engage with generative AI tools. This finding is consistent with the DigCompEdu framework (Redecker, 2017), which conceptualizes digital competence as a combination of technical, pedagogical, and critical capacities required for effective technology integration in education. From this perspective, the results reinforce the idea that digital competence functions as a foundational condition for meaningful technological innovation in higher education.

These findings are also aligned with previous research highlighting the importance of digital competence in shaping the adoption of educational technologies. Cabero-Almenara and Barroso-Osuna (2020) have shown that many university instructors still face limitations in integrating digital tools pedagogically, while Krumsvik (2018) emphasizes that higher levels of digital competence are associated with greater confidence and willingness to adopt new technologies. The patterns observed in this study reflect similar dynamics, suggesting that educators with stronger digital skills are better positioned to explore the pedagogical potential of generative AI.

Another key dimension emerging from the results is the role of institutional support. The analysis indicates that faculty readiness for AI adoption increases in institutions that provide adequate technological infrastructure, professional development opportunities, and clear policy guidelines. In particular, access to training programs appears to be especially relevant, as it directly influences educators' capacity to understand and apply new technologies in their teaching practices. This finding supports previous work emphasizing the importance of institutional ecosystems in enabling digital transformation in higher education (Cabero-Almenara & Barroso-Osuna, 2020).

Technological infrastructure also plays a significant role in shaping adoption readiness. Universities that offer stable internet connectivity, access to digital platforms, and appropriate technological resources create more favorable conditions for innovation. However, as highlighted in the literature on digital inequality, access alone is not sufficient. Van Deursen and Van Dijk (2019) argue that differences in the quality of access and in digital skills remain critical factors influencing effective technology use. In higher education contexts, these structural conditions directly affect educators' ability to integrate emerging technologies such as generative AI into their teaching practices.

The relevance of these institutional factors becomes even more evident when considering the context of Paraguay and, more broadly, Latin America. In many cases, digital transformation processes occur under conditions of limited resources and structural inequalities. As noted by Van Dijk (2020), the digital divide has evolved from issues of access to more complex disparities related

to skills and outcomes. The findings of this study suggest that addressing these challenges requires integrated strategies that combine investments in infrastructure with sustained efforts in teacher training and institutional development.

The study also provides insights into faculty perceptions of generative AI technologies. While participants generally recognized the potential of AI to enhance teaching and learning processes, concerns related to ethics, academic integrity, and reliability were also evident. These concerns reflect broader debates in the literature on AI in education. Floridi et al. (2018) and Jobin et al. (2019) emphasize the importance of developing ethical frameworks to guide the responsible use of AI technologies. In this sense, strengthening digital competence may also contribute to fostering more critical and reflective engagement with AI systems.

From a pedagogical perspective, the findings support the view that generative AI should not be understood as a replacement for teachers, but rather as a tool that can augment their capabilities. As argued by Hwang et al. (2020), AI has the potential to support adaptive learning and personalized instruction, but its effectiveness depends on how educators interpret and apply these tools. The results of this study reinforce this perspective, highlighting the continued centrality of teachers in AI-mediated educational environments.

Furthermore, the machine learning analysis provides additional insights into the complexity of the relationships between variables. As shown in Table 3, ensemble models such as Random Forest and Gradient Boosting achieved higher predictive performance than Logistic Regression, suggesting the presence of nonlinear interactions among digital competence, institutional factors, and attitudinal variables. This indicates that faculty readiness for AI adoption is not determined by a single factor, but rather emerges from the interaction of multiple dimensions operating simultaneously.

Finally, the results provide evidence that the limited body of research on AI adoption in higher education within the Global South. By focusing on Paraguay, it highlights the importance of considering contextual factors when analyzing digital transformation processes. As noted by Heeks, Ospina, and Wall (2021), technological innovation in developing contexts must be understood in relation to broader issues of inclusion and inequality. The findings presented here provide empirical evidence that can inform both academic research and policy development in this area.

Despite its contributions, the study also has limitations. The cross-sectional design does not allow for causal inference, and the use of self-reported data may introduce bias. In addition, the conceptual proximity between some variables suggests the need for more refined measurement instruments in future research. Longitudinal studies and the inclusion of behavioral indicators—such as actual use of AI tools in teaching—would provide a more comprehensive understanding of adoption processes.

In summary, the findings highlight the importance of digital teaching competence and institutional support as key factors in the adoption of generative AI in higher education. At the same time, they underscore the need for cautious interpretation of predictive models when working with conceptually related variables. Strengthening teacher training, improving infrastructure, and developing clear ethical frameworks will be essential for ensuring that the integration of AI technologies contributes to sustainable and meaningful educational transformation.

4.1. Limitations

This study presents several limitations that should be considered when interpreting its findings. First, the research is based on a cross-sectional survey design, which limits the ability to establish causal relationships between digital teaching competence, institutional conditions, and faculty readiness for Generative Artificial Intelligence (GAI) adoption. Although the statistical and machine learning analyses provide insights into predictive associations among variables, longitudinal research would be necessary to examine how these relationships evolve over time as universities continue to integrate AI technologies into their teaching practices.

Second, the data were collected through self-reported questionnaires, which may introduce potential biases related to respondents' perceptions or social desirability. Faculty members may

overestimate or underestimate their own levels of digital competence or readiness to adopt emerging technologies. While self-report measures are commonly used in educational technology research, future studies could complement this approach with objective indicators of digital competence, classroom observations, or analysis of actual technology use in teaching environments.

Third, the study focuses specifically on public higher education institutions in Paraguay, which may limit the generalizability of the findings to other national or institutional contexts. Higher education systems vary considerably in terms of technological infrastructure, digital transformation strategies, and institutional governance structures. Therefore, caution should be exercised when extrapolating these results to universities in other regions. Comparative studies involving multiple countries or educational systems could provide broader insights into how contextual factors influence faculty readiness for AI adoption.

Fourth, although the research incorporates machine learning techniques to identify predictors of readiness for generative AI adoption, the models rely on the variables included in the survey instrument. Other potentially relevant factors—such as disciplinary differences, institutional leadership strategies, or student expectations—were not explicitly examined in this study. Future research could expand the analytical framework by incorporating additional variables that capture the complexity of technological innovation in higher education.

Finally, while the conceptual model developed in this study provides a useful framework for understanding the role of digital competence in AI adoption, further empirical validation is necessary. Future studies should aim to test and refine the proposed relationships using larger datasets, experimental designs, or mixed-method approaches, thereby contributing to a more comprehensive understanding of how generative AI technologies can be responsibly and effectively integrated into higher education systems.

4.2. Future Directions

Building on the findings of this study, future research should focus on advancing empirical and intervention-based approaches that move beyond descriptive analyses of faculty readiness for Generative Artificial Intelligence (GAI) adoption in higher education. One important direction involves the implementation and evaluation of structured professional development programs aimed at strengthening digital teaching competence. Such initiatives may include specialized workshops on AI-assisted pedagogy, training modules on ethical AI use in education, and interdisciplinary programs that combine technological literacy with pedagogical innovation. Longitudinal studies tracking faculty participation in these programs could provide valuable evidence on whether improvements in digital competence translate into greater readiness and more effective integration of generative AI tools in teaching practices.

Another promising avenue concerns the exploration of psychological and pedagogical mechanisms that mediate the relationship between digital competence and AI adoption readiness. Variables such as technological self-efficacy, innovation attitudes, pedagogical flexibility, and openness to experimentation may play important roles in shaping how educators engage with emerging AI technologies. Investigating these mediating factors would contribute to the development of more comprehensive explanatory models that clarify how competence frameworks translate into actual instructional practices.

Future research should also examine the pedagogical impact of generative AI integration on teaching and learning processes. While the present study focuses primarily on faculty readiness and institutional conditions, subsequent investigations could analyze how AI-assisted tools influence instructional design, assessment practices, student engagement, and learning outcomes. Mixed-method designs combining quantitative analysis with qualitative classroom observations could provide deeper insights into the practical implications of AI adoption within real educational environments.

In addition, comparative research across different institutional and regional contexts would significantly enrich the current understanding of AI adoption in higher education. Higher education

systems vary widely in terms of technological infrastructure, governance models, and digital transformation strategies. Cross-national studies involving universities from Latin America, Europe, and other regions could help identify common patterns as well as context-specific challenges in the integration of generative AI technologies.

Another important research direction involves the development of more refined measurement instruments for digital teaching competence and AI-related pedagogical skills. While frameworks such as DigCompEdu provide a valuable conceptual foundation, emerging technologies like generative AI introduce new competencies related to algorithmic understanding, AI-assisted content creation, and human–AI collaboration in educational contexts. Future work should therefore aim to operationalize these competencies more precisely and validate measurement scales capable of capturing these evolving skill sets.

Finally, future research should explore how institutional strategies and educational policies can support responsible AI integration in higher education systems. Universities increasingly face the challenge of balancing technological innovation with ethical considerations related to academic integrity, data privacy, and transparency in AI-assisted decision-making. Policy-oriented studies examining governance frameworks, institutional guidelines, and regulatory approaches will be essential for ensuring that the adoption of generative AI technologies contributes to sustainable, inclusive, and pedagogically meaningful digital transformation in higher education.

5. Conclusions

This study examined the relationship between digital teaching competence and faculty readiness for the adoption of Generative Artificial Intelligence (GAI) in public higher education institutions in Paraguay. The findings demonstrate that digital competence, when understood as a multidimensional construct that integrates technological, pedagogical, and critical capacities, plays a central enabling role in supporting educators' engagement with emerging AI technologies. Rather than being limited to basic technical skills, digital teaching competence encompasses the ability to critically evaluate digital resources, design technology-enhanced learning environments, and collaborate effectively with AI-assisted tools in pedagogical contexts.

The results reinforce the idea that digital competence functions as a key driver of technological adoption in higher education. Faculty members with stronger digital competencies reported higher levels of readiness to experiment with generative AI tools and to integrate these technologies into their teaching practices. This finding is consistent with established digital competence frameworks such as DigCompEdu (Redecker, 2017), which emphasize that educators' digital skills must combine technical proficiency with pedagogical and ethical awareness. Similarly, previous research highlights that the effective integration of digital technologies in education depends largely on educators' ability to interpret and apply these tools in pedagogically meaningful ways (Cabero-Almenara & Barroso-Osuna, 2020; Krumsvik, 2018).

Another key contribution of the study concerns the role of institutional environments in shaping AI adoption readiness. The results indicate that technological infrastructure, professional development opportunities, and institutional policies supporting digital innovation significantly influence faculty preparedness to engage with AI technologies. These findings align with broader research on digital transformation in education, which stresses that technological change is not driven solely by access to tools but also by supportive organizational ecosystems that encourage experimentation and innovation (Van Deursen & Van Dijk, 2019; Van Dijk, 2020).

In addition to technological and institutional factors, the study also highlights the importance of ethical and governance considerations in the adoption of AI in higher education. The rapid development of generative AI tools has generated increasing debate regarding issues such as academic integrity, transparency, and responsible use of automated systems in educational contexts. Scholars such as Floridi (2021) and Jobin, Ienca, and Vayena (2019) emphasize that ethical governance frameworks are essential for ensuring that AI technologies contribute to socially beneficial outcomes. In this regard, strengthening educators' digital competence may help foster more critical and

responsible engagement with AI-driven technologies. Furthermore, discussions on digital information ecosystems and algorithmic influence highlight the need for stronger digital literacy and critical awareness among users in order to mitigate risks related to misinformation and manipulation in digital environments (Benkler, 2016).

From a broader perspective, the findings suggest that digital competence plays an important role in supporting human agency within AI-mediated educational environments. Rather than replacing teachers, generative AI technologies should be understood as tools that extend human capabilities and support more adaptive and personalized learning processes. Research on artificial intelligence in education similarly highlights that AI systems can enhance educational experiences when educators remain actively involved in guiding, interpreting, and contextualizing AI-generated outputs (Hwang et al., 2020; Zawacki-Richter et al., 2019). At the same time, emerging research on digital behavior and technology use suggests that digital competence can function as a regulatory resource that helps individuals maintain balanced and responsible engagement with digital technologies (Brand et al., 2019; Compas & Jaser, 2020).

The study also contributes to discussions on digital transformation in higher education within the Global South, where technological innovation often intersects with structural inequalities in access to digital resources and training opportunities. Scholars such as Heeks, Ospina, and Wall (2021) and Hilbert (2020) argue that digital development processes must address not only technological infrastructure but also broader social and educational conditions that shape participation in digital societies. By focusing on Paraguay's public higher education system, this research provides insights into how strengthening digital competence among faculty may support more inclusive participation in emerging AI-driven educational environments.

From a practical standpoint, the findings carry important implications for universities, teacher education programs, and policymakers. Investments in digital infrastructure alone are insufficient to ensure effective technological integration in higher education. Instead, institutions should prioritize comprehensive strategies that combine infrastructure development with continuous professional training in digital pedagogy and AI literacy. Such strategies may include specialized workshops on AI-assisted teaching, interdisciplinary training programs on responsible AI use, and the development of institutional guidelines that clarify ethical and pedagogical standards for AI integration in academic contexts.

Finally, the study highlights that digital competence may also play a protective role in managing the broader social and behavioral implications of digital technologies. Research on problematic technology use and digital behavior indicates that individuals with higher levels of digital competence tend to demonstrate greater capacity for self-regulation and critical engagement with digital environments (Elhai et al., 2019; Tao et al., 2023). Strengthening digital competence among educators may therefore contribute not only to technological innovation in teaching but also to healthier and more reflective interactions with digital systems.

Overall, this study highlights the central role of digital teaching competence as a foundational element for responsible and effective adoption of generative AI technologies in higher education. As AI continues to reshape educational landscapes, strengthening educators' digital competencies will be essential for ensuring that technological innovation contributes to pedagogical improvement, ethical awareness, and inclusive digital transformation. By positioning digital competence at the intersection of education, technological innovation, and institutional governance, this research contributes to ongoing debates on how higher education systems can navigate the opportunities and challenges of AI-driven digital futures.

Supplementary Materials: No additional supplementary datasets are publicly available for this article. The study is based on survey data collected from university faculty in Paraguayan public higher education institutions. Due to privacy and confidentiality considerations related to the participating institutions and respondents, the dataset cannot be made publicly accessible. However,

anonymized data supporting the findings of this study may be obtained from the corresponding author upon reasonable request.

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Informed Consent Statement: Informed consent was obtained from all participants involved in the study. Before completing the questionnaire, participants were informed about the objectives of the research, the voluntary nature of participation, and the confidentiality and anonymous treatment of their responses.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request. Due to privacy considerations related to the participating institutions and respondents, the dataset is not publicly available.

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Abbreviations

The following abbreviations are used in this manuscript:

| | |
|----------------|--|
| AI | Artificial Intelligence |
| GAI | Generative Artificial Intelligence |
| DC | Digital Competence |
| DTC | Digital Teaching Competence |
| ML | Machine Learning |
| LLMs | Large Language Models |
| NLP | Natural Language Processing |
| HE | Higher Education |
| HEIs | Higher Education Institutions |
| AUC-ROC | Area Under the Receiver Operating Characteristic Curve |

| | |
|-----------------|---------------------------------------|
| F1-score | Harmonic Mean of Precision and Recall |
|-----------------|---------------------------------------|

Appendix A. Illustrative sample of items

This appendix presents illustrative examples of items included in the questionnaire used to assess digital teaching competence, attitudes toward Generative Artificial Intelligence (GAI), institutional support, and readiness for AI adoption among university faculty in Paraguay. The items are adapted from established digital competence frameworks and previous research on technology adoption in higher education.

The indicators presented below are intended to illustrate the types of questions included in the survey instrument and the conceptual dimensions measured in the study. All items were measured using a five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Digital Teaching Competence

I feel confident using digital technologies to support my teaching activities.

I am able to design learning activities that incorporate digital tools effectively.

I can evaluate the reliability and relevance of digital resources used in my courses.

Attitudes toward Generative Artificial Intelligence

- Generative AI tools can enhance the quality of teaching and learning processes.
- AI technologies can support personalized learning experiences for students.
- I am interested in experimenting with generative AI tools in my teaching activities.

Institutional Support and Infrastructure

- My institution provides adequate technological resources to support digital teaching.
- Training opportunities related to digital technologies are available at my university.
- My institution encourages the exploration of innovative digital tools in teaching.

Readiness for Generative AI Adoption

- I feel prepared to integrate generative AI tools into my teaching practices.
- I would be willing to use AI-based tools for content generation or feedback in my courses.
- I believe generative AI will play an important role in the future of higher education.

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