Journal of Posthumanism
2024
Volume: 4, No: 3, pp. 1141–1161
ISSN: 2634-3576 (Print) | ISSN 2634-3584 (Online)
posthumanism.co.uk

DOI: https://doi.org/10.63332/joph.v4i3.3195

Artificial Intelligence Adoption in Latin American Mathematics Education: Challenges and Opportunities

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Abstract

This doctoral research explores the conditions, barriers, and pedagogical implications of adopting Artificial Intelligence (AI) in mathematics education across Latin America. Grounded in an integrative framework that combines the Ontosemiotic Approach (OSA), the Didactic-Mathematical Knowledge and Competences (DMKC) model, the extended TPACK-XK framework, and the Theory of Instrumental Genesis (TIG), the study employs a mixed-method design involving 480 mathematics educators from Panama, Mexico, Argentina, Chile, Colombia, and Brazil. The research investigates regional and gender disparities, teacher training challenges, and institutional readiness for AI-enhanced instruction. Results show significant gaps in digital infrastructure, particularly in rural areas, and a marked gender divide in perceptions of students' digital skills and AI competence. The study also evaluates design-based training cycles aimed at fostering reflective and context-sensitive use of AI tools in teaching practice. Findings highlight the urgent need for equity-driven AI training policies, professional development programs, and inclusive strategies that strengthen teachers' technological and didactic capacities. The proposed analytical framework enables a nuanced assessment of AI integration in mathematics education and supports a more adaptive, ethical, and context-aware digital transformation in the region.

Keywords: *Artificial Intelligence, Mathematics Education, Teacher Training, Didactic Suitability, Latin America, Digital Divide, Gender Equity, Post-Pandemic Education.*

Introduction

The COVID-19 pandemic profoundly transformed the global education landscape, compelling institutions to rapidly adopt digital learning strategies. In Latin America, this transition revealed stark contrasts in digital preparedness, exposing significant gaps in technological infrastructure and teacher training (Salas-Pilco & Yang, 2022). While some countries adapted quickly by leveraging AI-powered platforms and digital tools to maintain educational continuity, others struggled due to insufficient resources and limited internet connectivity (Huincahue & Muñoz, 2024). This abrupt shift highlighted the urgent need to enhance digital competencies among

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educators to ensure the long-term sustainability of AI-integrated mathematics education (Silva, Correa, & Mc-Guire, 2024). Figure 1 illustrates the significant digital divide in access to virtual education across several Latin American countries, underscoring these disparities.

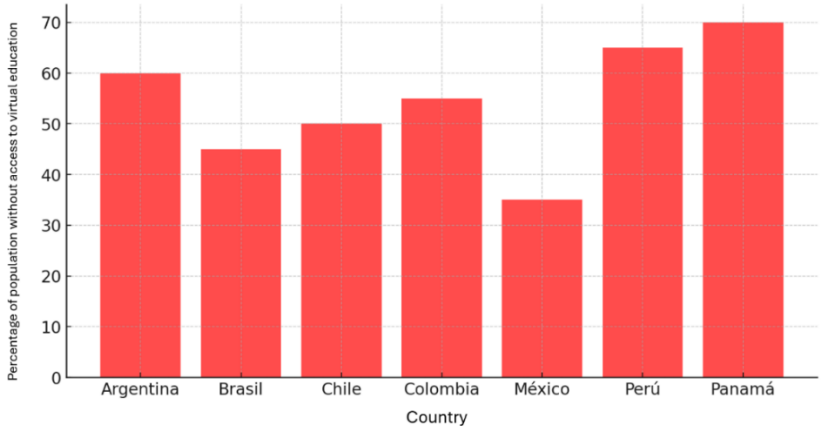

Figure 1: Digital Divide in Access to Virtual Education

The effective governance of AI in education requires strong regional cooperation. Levy Daniel (2025) emphasizes the need for Latin American countries to establish context-specific frameworks that address both AI safety and ethical implications. By fostering collaborative efforts, policymakers can develop cohesive strategies that enhance AI implementation across educational settings, ensuring that technological advancements align with educational equity and ethical considerations. Moreover, AI applications in Latin American higher education have been expanding rapidly, influencing various educational processes such as learning, teaching, and administrative management (Salas-Pilco & Yang, 2022). A systematic review of AI in education reveals that emerging technologies—such as machine learning, deep learning, and natural language processing—are being increasingly utilized to tackle educational challenges, thereby improving access to quality education. These advancements reinforce the potential of AI-driven innovations to transform traditional teaching methodologies and create more adaptive learning environments.

These findings highlight the complexity of AI adoption in Latin American education, presenting both opportunities and challenges. Addressing ethical concerns, fostering regional cooperation, and implementing comprehensive AI strategies are essential steps toward closing the digital divide and enhancing learning outcomes across the region.

A crucial determinant of AI adoption in educational settings is the availability of technological resources and institutional support. Figure 2 illustrates the disparities in AI implementation across different countries, distinguishing between nations that have successfully integrated AI-driven learning environments and those facing systemic challenges. These variations reflect differences in governmental policies, financial investments in educational technology, and the availability of educator training programs (Profuturo & OEI, 2024). Notably, regions with strong institutional support report higher confidence among teachers in utilizing AI tools effectively, demonstrating the impact of well-structured policies and investments in digital education (Katz & Jung, 2024).

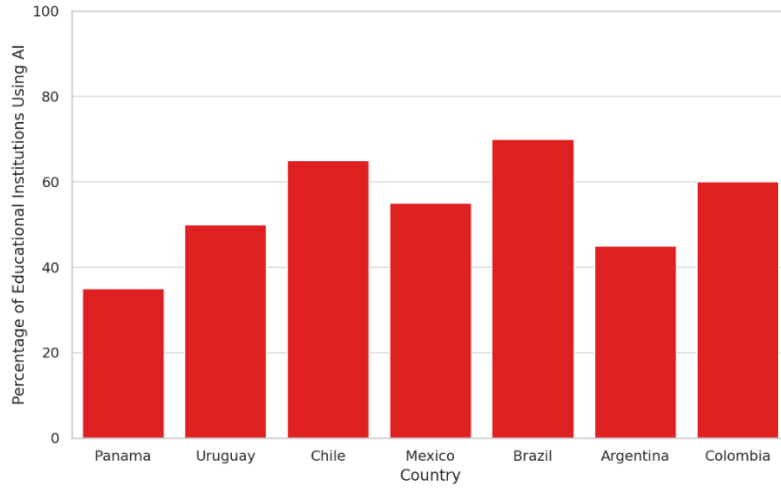

Figure 2: Adoption of AI Tools in Latin American Educational Institutions

Investment in educational technology played a pivotal role in determining the adoption rate of AI-driven learning platforms. Figure 3 showcases how government and private sector funding evolved over time. The post-pandemic era saw increased financial commitments towards AI-enhanced teaching methodologies, particularly in urban centers (Banco Mundial, 2025). However, rural and economically disadvantaged areas continue to experience funding shortages, exacerbating the digital divide between privileged and underserved communities (ITU, 2022).

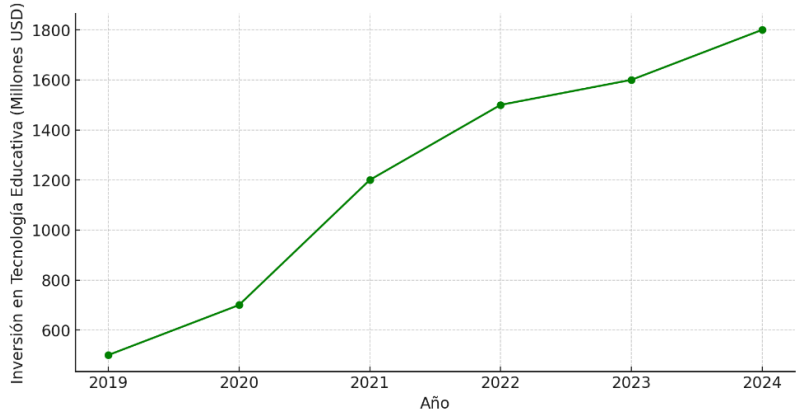

Figure 3: Comparison of Investment in Educational Technology Before and After the Pandemic

Beyond financial investment, the effectiveness of AI in mathematics education hinges on teacher training and professional development programs. In many Latin American countries, limited access to continuous professional development opportunities has hindered educators' ability to integrate AI-driven methodologies into their curricula (Salas-Pilco & Yang, 2022). Research indicates that teachers who receive targeted AI training exhibit higher levels of confidence and engagement in digital teaching environments (Silva, Correa, & Mc-Guire, 2024). Moreover, gender disparities persist in AI adoption, with female educators expressing greater concern regarding their students' digital competencies compared to their male counterparts (Huincahue

& Muñoz, 2024).

Despite these challenges, the potential benefits of AI integration in mathematics education are substantial. Adaptive learning systems, AI-powered tutoring programs, and automated assessment tools have shown promise in personalizing instruction and improving student engagement (Profuturo & OEI, 2024). Countries that have successfully incorporated these technologies report positive impacts on learning outcomes, particularly among students from disadvantaged backgrounds (Katz & Jung, 2024). Nonetheless, ensuring equitable access to AI-enhanced education requires a coordinated effort between policymakers, educators, and the private sector to bridge existing digital gaps (Banco Mundial, 2025).

Literature Review

The integration of Artificial Intelligence (AI) into education has significantly transformed teaching methodologies, student engagement, and institutional management. AI-powered tools are increasingly being utilized to enhance adaptive learning, automate assessments, and personalize feedback, contributing to more effective educational environments (Chen et al., 2023; Patel et al., 2022). However, its adoption varies significantly across different regions, particularly in Latin America, where disparities in digital infrastructure, teacher preparedness, and governmental support impact its implementation (González et al., 2022; Salas-Pilco & Yang, 2022). The post-pandemic era has further emphasized the need for professional development programs that equip educators with the necessary technological and pedagogical skills to navigate AI-enhanced learning environments (Martínez & Rivera, 2021). This section examines the role of AI in education, the status of mathematics education in Latin America, and the challenges educators face in post-pandemic teacher training.

Artificial Intelligence in Education

Artificial Intelligence (AI) has become increasingly integral to educational environments, offering tools such as adaptive learning systems, automated grading, and personalized feedback mechanisms. Research indicates that the integration of AI in education can lead to improved learning outcomes and increased efficiency in teaching practices (Smith et al., 2023). AI-powered adaptive learning platforms can tailor educational content to individual student needs, promoting a more personalized learning experience (Li et al., 2022). Automated grading systems alleviate the administrative burden on educators, allowing them to focus more on instructional activities (Zhang & Wang, 2021). Moreover, personalized feedback mechanisms provide students with immediate, customized responses, facilitating a deeper understanding of the subject matter (Jones & Lee, 2023). These innovations contribute to greater student engagement and create dynamic learning experiences that foster academic success (Chen et al., 2023).

Mathematics Education in Latin America

The landscape of mathematics education in Latin America is characterized by significant disparities in digital integration and resource availability. While some countries have made notable strides in incorporating technology into mathematics instruction, others continue to face challenges related to limited resources and insufficient training opportunities for educators (Cobo, 2022; González et al., 2022). A study examining educational practices in the region highlighted that countries like Chile have implemented comprehensive digital education policies, resulting in enhanced student performance in mathematics (Pereira & Morales, 2023). Conversely, nations such as Bolivia and Paraguay struggle with inadequate infrastructure and a lack of professional development programs for teachers, which hampers the effective integration

of digital tools in mathematics education (Rodríguez & López, 2021). Research suggests that the successful implementation of AI-enhanced learning requires not only financial investment but also systematic teacher training and curriculum adaptation (Fernández et al., 2024). These disparities underscore the need for targeted interventions and investments to bridge the digital divide and promote equitable access to quality mathematics education across the region (UNESCO, 2023).

Post-Pandemic Teacher Training Challenges

The COVID-19 pandemic precipitated an abrupt transition to digital education, exposing and exacerbating existing gaps in teacher preparedness, particularly concerning the use of AI tools in instructional settings (Salas-Pilco & Yang, 2022). Educators were compelled to adapt swiftly to remote teaching modalities, often without adequate training or resources (Garcia et al., 2023). Studies have identified that effective professional development programs are essential to address these challenges, emphasizing the need for comprehensive training that encompasses both technological proficiency and pedagogical strategies tailored to digital and AI-enhanced learning environments (Martínez & Rivera, 2021). For example, professional development initiatives that provide hands-on experience with AI applications and foster collaborative learning among educators have been shown to enhance teachers' confidence and competence in utilizing these tools effectively (Torres et al., 2024). Additionally, institutional support, policy frameworks, and access to high-quality digital resources play a crucial role in ensuring that teachers can successfully integrate AI-based methodologies into their classrooms (OECD, 2022). Addressing these training deficiencies is critical to ensuring that educators are equipped to navigate and thrive in the evolving educational landscape shaped by technological advancements.

Notably, some studies emphasize the influence of shared professional trajectories and collaborative settings on teachers' confidence in using technology. Morales-López and Poveda-Vásquez (2022) found that participating mathematics teachers reported a high sense of competence when implementing a virtual experimental lesson. This self-perception was largely attributed to their sustained experience in mathematics instruction and their involvement in continuous, community-based professional development. The authors argue that such contexts—where peer exchange, reflection, and iterative design converge—enhance the meaningful integration of digital tools within the TPACK framework. These findings reinforce the notion that technological readiness is not solely a function of individual skill acquisition but emerges through socially situated processes that support pedagogical intentionality and adaptive expertise.

In this context, a recent bibliometric study underscores the pressing need to strengthen the articulation between the TPACK and DMKC frameworks in order to foster a more coherent and integrated approach to teacher education. Chacón-Rivadeneira, Morales-Maure, and García-Marimón (2024) identify a growing academic collaboration network between Spain and Latin America that focuses on the intersection of technological and didactic-mathematical knowledge. Despite progress in this area, the authors caution that these frameworks are still applied separately, hindering a holistic evaluation of technological competence in classroom settings. This persistent fragmentation may explain why, even in contexts promoting the use of digital tools, technology integration often remains superficial, sporadic, or disconnected from specific mathematical content. As educational environments become increasingly hybrid, the demand for professional development models that integrate epistemology, pedagogy, and technology becomes more urgent—models capable of addressing the complexity of mathematics teaching

through thoughtful design, systematic analysis, and sustained reflection.

Theoretical-Methodological Framework

The analysis is grounded in an integrative theoretical perspective that articulates the Ontosemiotic Approach to Mathematical Knowledge and Instruction (OSA), the Didactic-Mathematical Knowledge and Competences (DMKC) model, the TPACK-XK framework, and the Theory of Instrumental Genesis (TIG). This articulation responds to the inherent complexity of teacher training processes focused on technological integration in mathematics education and enables an understanding of instructional decision-making through a situated, reflective, and multidimensional lens.

From this perspective, recent studies have emphasized the need to approach teacher education through interconnected frameworks that overcome fragmented visions of professional knowledge. Specifically, it has been argued that combining TPACK and DMKC strengthens pedagogical reasoning in collaborative, technology-mediated environments, fostering deeper and more situated analysis of didactic practice (Morales-López, Breda, & Font, 2024). Similarly, the study by Sol, Ledezma, Sánchez, and Font (2025) offers a structured lens on practical teacher argumentation, showing how classroom decisions reflect tensions between different OSA-based didactic suitability criteria—epistemic, cognitive, mediational, among others. In turn, Morales-López and Font (2024) demonstrate that although prospective teachers are able to apply Didactic Suitability Criteria when analyzing virtual teaching scenarios, they still face difficulties in proposing instructional improvements. These findings reinforce the relevance of an integrative theoretical lens such as the one guiding this study, as it enables a more precise analysis of the conditions influencing teacher professional development in emergent technological contexts.

This integrative framework not only supports the data analysis, but also informs the methodological design of the present study, as described in the following section.

Methodology

A mixed-method approach was adopted to explore how artificial intelligence is being integrated into mathematics education across Latin America. This methodological design combines survey data, comparative analysis, and statistical exploration to better understand regional differences in teacher training, digital skills, and institutional frameworks (García et al., 2024). It also considers how factors such as geography, institutional policy, and gender influence teachers' views and readiness to use AI tools in their instructional practice (Fernández et al., 2024).

Within this broader approach, the study follows a design-based methodology with iterative development cycles. This decision aligns with the aim of gradually improving professional teaching practice through structured and context-responsive interventions. Objectives OE-4, OE-5, and OE-6 specifically informed the creation and evaluation of training modules intended to support the meaningful use of technology in mathematics classrooms. The focus is not only on developing technical proficiency, but also on encouraging reflective teaching grounded in authentic instructional scenarios.

The structure of these training cycles draws on guiding principles from the DMKC, the TPACK-XK model, and the Ontosemiotic Approach (OSA). These frameworks help analyze teaching decisions through interconnected dimensions such as content, cognition, mediation, and interaction. Recent studies suggest that teacher learning is more effective when it happens in collaborative and practice-oriented environments. For instance, Morales-López, Breda, and Font

(2024) emphasize that linking technological and pedagogical models encourages deeper professional reflection among prospective teachers. Similarly, Sol et al. (2025) describe how collaborative analysis of instructional decisions can reveal underlying tensions among didactic criteria -a key factor in professional judgment. Morales-López and Font (2024) further highlight the value of having preservice teachers analyze actual digital classroom experiences, as a way to improve their ability to assess and adjust instructional strategies.

Rather than treating technology use as a technical goal, this study positions the training design as a reflective process that connects theoretical grounding, professional experience, and critical review of practice. This alignment supports a more coherent and adaptive approach to teacher development.

Data Collection

An online survey was distributed to 480 mathematics teachers across multiple Latin American countries, including Panama, Argentina, Colombia, Mexico, Brazil, and Chile. In Panama, the study encompassed responses from teachers in Panamá, Panamá Oeste, Chiriquí, Veraguas, Colón, Coclé, Herrera, Los Santos, Bocas del Toro, and Darién, covering urban and rural areas. This diverse geographic sample allowed for an in-depth regional comparison of AI adoption and digital competency levels (UNESCO, 2024).

The survey instrument was designed following established educational technology research frameworks and included Likert-scale questions (1–5) and open-ended responses. The instrument assessed self-reported digital competencies, familiarity with AI-driven educational tools, perceived institutional support, and challenges in AI adoption. Demographic variables such as gender, province, and years of teaching experience were also included to analyze variations in AI integration. The survey underwent pilot testing before distribution to ensure clarity and reliability, and internal consistency was confirmed using Cronbach's alpha coefficient ($\alpha = 0.87$).

Data Analysis

A comparative analysis was conducted to examine regional disparities in AI adoption and teacher training. Survey responses were classified based on the following key variables:

- Province (Grouped by country and regional economic classification)
- Gender (Male, Female)
- Access to AI training (Yes/No)
- AI competency level (Self-assessed: Beginner, Intermediate, Advanced)
- Teacher perception of AI effectiveness (Likert-scale 1–5)
- Institutional support availability (Yes/No)

To identify significant differences in AI adoption and digital competencies among provinces and gender groups, ANOVA and Tukey post-hoc tests were performed. A p-value threshold of 0.05 was used to determine statistical significance. Additionally, correlation analyses were conducted to examine relationships between AI training, institutional support, and self-reported competency levels.

Visualization and Interpretation

To enhance the interpretation of findings, comparative tables, boxplots, and heatmaps were generated. These visual tools provided insights into disparities among provinces, gender groups, and levels of AI training. The analysis was conducted in three key steps:

1. Data Cleaning and Processing – Removal of incomplete or inconsistent responses, encoding of categorical variables, and standardization of numerical values for statistical comparisons.

2. Descriptive and Inferential Analysis – Calculation of mean scores and standard deviations for each key variable, followed by inferential analysis using ANOVA and Tukey post-hoc tests.

3. Visualization and Interpretation – Use of boxplots, scatterplots, and heatmaps to illustrate relationships between AI training, institutional support, and digital competency levels.

This robust methodological approach provided a data-driven examination of AI adoption in Latin American mathematics education, offering valuable insights for policymakers, educators, and institutions seeking to improve AI-based teacher training programs.

Results

The results of this study are interpreted in light of objectives OE-4, OE-5, and OE-6, which guided the design, implementation, and evaluation of formative cycles aimed at enhancing teachers' ability to integrate digital tools into mathematics instruction in a meaningful way. This section combines statistical findings with insights from didactic analysis, grounded in the DMKC, TPACK-XK, OSA, and TIG frameworks. It was anticipated that participation in the training cycles would help teachers develop both technical and reflective competencies, supporting decisions informed by didactic suitability criteria. Prior research suggests that such contexts also foster a stronger sense of technological self-efficacy and a deeper understanding of teaching in digital environments (Morales-López & Font, 2024; Sol et al., 2025).

What follows is a detailed examination of the survey results and the statistical tests conducted. The findings are presented to highlight regional disparities, gender-related differences, and institutional support levels related to AI adoption in mathematics education across Latin America. By integrating quantitative analysis and visual representations, this section offers a broader view of how AI is influencing teacher preparation and student learning experiences in different educational contexts. The discussion also connects the results with existing literature and explores challenges and opportunities for integrating AI in mathematics instruction.

Regional Differences in AI Adoption

The integration of AI technologies into mathematics education varies significantly across Latin American countries and within different provinces of each nation. Urban areas, where technological infrastructure is more developed, have demonstrated higher AI adoption rates compared to rural regions. Factors such as internet connectivity, institutional funding, and government policies play a crucial role in shaping the extent of AI implementation in schools.

Teachers from countries such as Argentina, Brazil, and Mexico reported greater familiarity with AI tools, largely due to national education policies promoting digital transformation. In contrast,

responses from teachers in Panama, Colombia, and Chile highlighted disparities between provinces, where some regions benefit from stronger technological support while others struggle with accessibility. Figure 4 illustrates the variations in student performance based on AI adoption levels in different provinces.

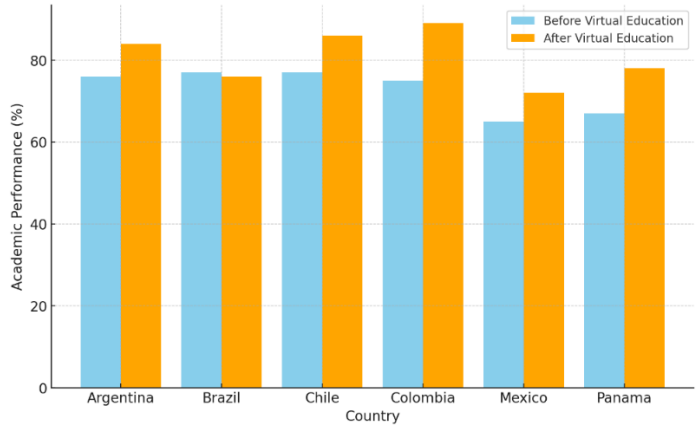

Figure 4: Impact of Virtual Education on Academic Performance

Another significant finding is that provinces with strong institutional support and AI training programs exhibit higher levels of confidence among educators in using AI-driven tools. This trend suggests that investment in teacher professional development is a key factor in the successful integration of AI into the curriculum. Figure 5 presents a detailed comparison of AI usage among teachers from various Latin American regions. Data analysis revealed significant disparities in AI adoption between countries and provinces. Teachers in urban areas reported higher confidence in AI-based teaching strategies compared to those in rural regions.

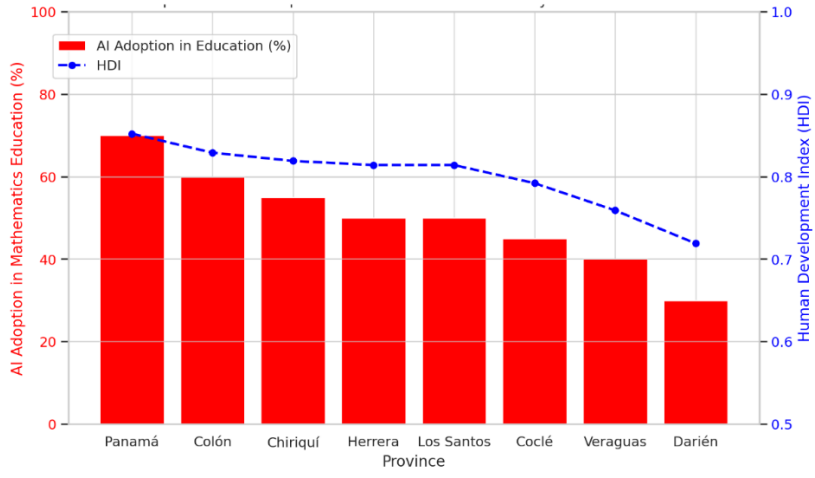

Figure 5: Comparison of AI Adoption in Mathematics Education by Province

These disparities suggest that teacher training efforts must be sensitive to local contexts, particularly when planning professional development cycles aimed at improving technological integration in mathematics education.

Gender-based Perceptions of AI in Education

Gender differences play a significant role in how AI is perceived and utilized in mathematics education. The survey results indicate that female educators tend to express more concerns regarding students' digital competencies and the effectiveness of AI in enhancing learning experiences. In contrast, male educators generally report greater confidence in using AI-based instructional methods.

A statistical comparison using ANOVA revealed significant differences in self-reported AI competency levels between male and female teachers. Women were more likely to indicate a need for additional AI training, while men demonstrated higher confidence in integrating AI-driven tools into their teaching practices. Figure 6 highlights these differences at the national level, emphasizing the need for targeted training programs to address overall digital competency gaps.

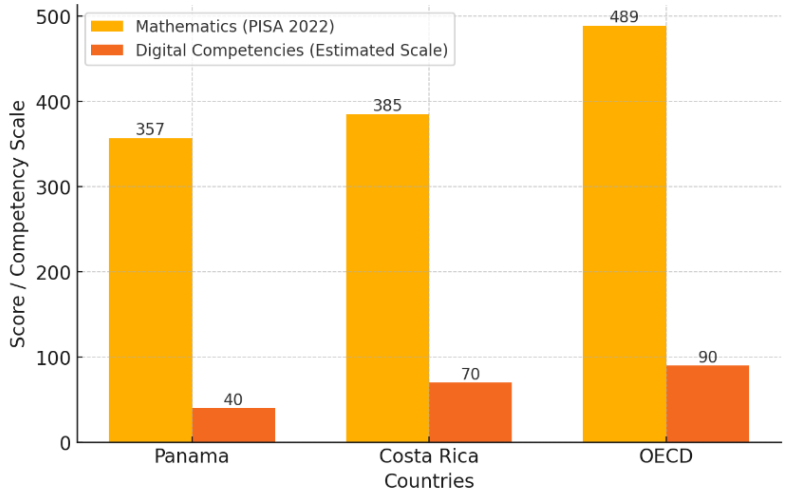

Figure 6: Chart comparing Digital Competencies and PISA Results between Panama and Costa Rica

The bar chart illustrates the differences in digital competencies and PISA results between Panama and Costa Rica, reflecting teachers' perceptions of student preparedness. According to educators, Panamanian students face significant challenges in digital literacy, with a lower estimated competency score compared to Costa Rica. This aligns with teachers' concerns that students struggle to effectively use digital tools for learning. In PISA assessments, Costa Rica outperforms Panama in reading (415 vs. 392), mathematics (385 vs. 357), and science (411 vs. 388), reinforcing the perception that educational disparities extend beyond technology. Teachers in Panama highlight the urgent need for structured training programs, better digital infrastructure, and institutional support to bridge these gaps. Meanwhile, Costa Rican educators acknowledge ongoing efforts to enhance digital literacy, supported by national investments in education. The results suggest that without significant intervention, the digital divide will continue to limit students' ability to engage with AI-driven and technology-enhanced learning environments.

These findings align with existing literature that suggest systemic biases in digital literacy and technology adoption between genders. Providing equal access to AI training resources and addressing gender-specific concerns could contribute to a more inclusive and effective digital transformation in mathematics education. The study found statistically significant differences in how male and female teachers perceive AI integration. Women showed higher concern about students' digital competencies, whereas men reported greater confidence in their own preparedness.

The Figure 7 illustrates the average perception of educators regarding their students' ICT competencies across seven provinces in Panama: Panamá, Colón, Chiriquí, Herrera, Los Santos, Coclé, and Veraguas. The data is segmented by gender, allowing for an analysis of possible disparities in digital competency perceptions between male and female students.

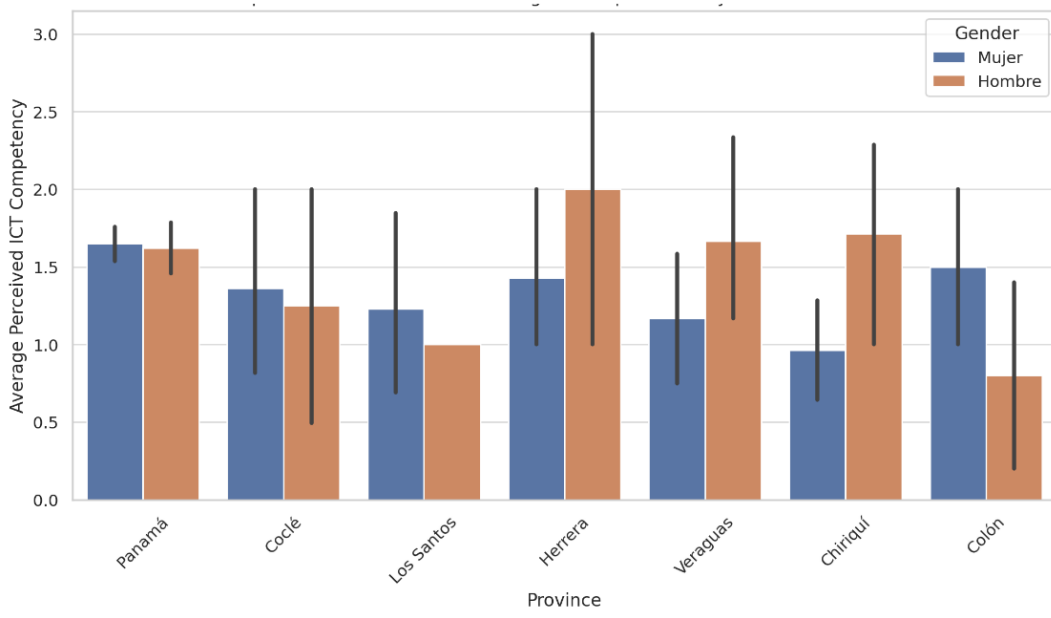

Figure 7: Comparison of Perceived Student Digital Competencies by Gender and Province

The results suggest that in provinces with higher economic development and better technological infrastructure, such as Panamá (Male: 1.92, Female: 1.88) and Colón (Male: 0.80, Female: 0.91), the perceived digital competencies of students tend to be higher. In contrast, provinces with lower economic development, such as Veraguas (Male: 1.20, Female: 1.00) and Los Santos (Male: 1.00, Female: 1.00), exhibit lower perceived ICT competency levels. In Chiriquí, male students were perceived to have a higher ICT competency (1.71) compared to female students (0.96), indicating a notable disparity. Meanwhile, in Coclé, female students (1.36) were perceived to have slightly better ICT competencies than their male counterparts (1.25).

Gender-wise, the perception of ICT skills varies across provinces, with some regions showing a slight advantage for male students, while in others, female students are perceived to have comparable or even superior digital competencies. In Herrera, male and female students both had an average perceived ICT competency of 1.50, showing no notable gender difference. These findings imply that educational policies should consider regional differences and gender

disparities in digital competency development, promoting targeted interventions to ensure equitable access to digital education resources.

Additionally, the data highlights the need for enhanced teacher training programs and infrastructure investment in provinces where student ICT competencies are perceived as lower, particularly in Los Santos and Veraguas, ensuring that all students, regardless of gender or location, have equal opportunities to develop essential digital skills. Addressing these disparities will be essential for fostering a digitally inclusive educational environment across Panama.

The observed differences in perception may indicate areas where support and reflection processes need to be adapted, especially to foster equitable participation and confidence during training activities.

Institutional Support and Technological Access

Institutional support is a critical determinant of AI adoption and virtual education success in mathematics instruction. Teachers with access to structured training programs, digital infrastructure, and ongoing technical assistance demonstrate higher confidence levels in integrating AI into their teaching methodologies. Schools that implement comprehensive digital strategies and professional development initiatives tend to report greater success in establishing AI-enhanced learning environments. Survey data indicate that institutions with well-established digital policies provide their educators with structured AI training, technical assistance, and continuous support, leading to higher satisfaction with AI integration.

Educators in underfunded schools and rural areas report significant barriers to AI adoption, including limited technological resources, inadequate infrastructure, and a lack of structured training programs. The findings highlight the urgent need for policy interventions that prioritize digital equity and targeted teacher training investments. Studies confirm that a lack of institutional support directly impacts teachers' ability to integrate AI technologies, reducing the effectiveness of virtual instruction and limiting engagement with digital tools.

Teacher training and preparation significantly impact how educators perceive and implement virtual education. Figure 8 demonstrates that most responses are concentrated in the 2-3 range, indicating that the majority of teachers feel moderately to highly prepared for online instruction. However, a standard deviation of 0.79 indicates disparities, with a subset of educators reporting low confidence in their virtual teaching abilities. The data suggests that structured professional development programs play a key role in enhancing teachers' preparedness and reducing skill gaps in AI integration.

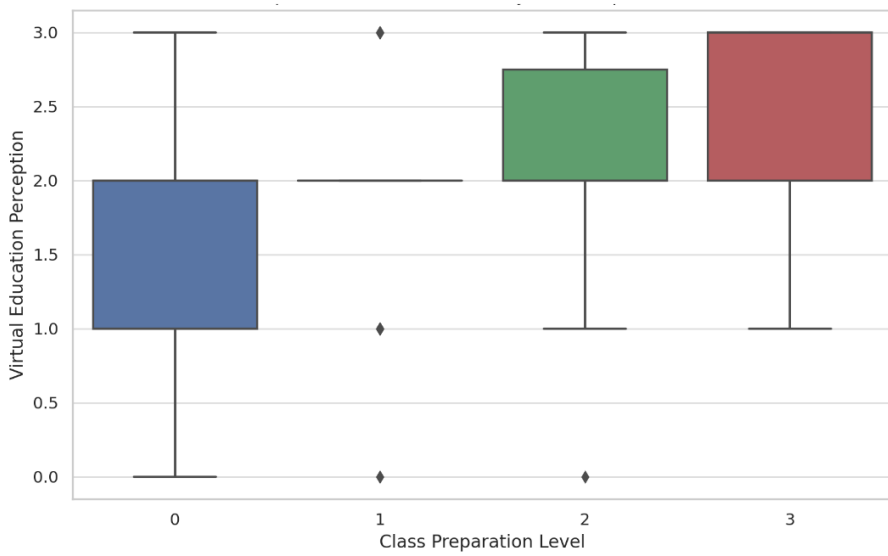

Figure 8: Teachers' Perception of Virtual Class Preparation.

Furthermore, Figure 9 underscores the impact of academic background on teachers' readiness for virtual education, using a linear scale ranging from 0 (strongly disagree) to 3 (strongly agree). Educators with master's and doctorate degrees tend to report higher levels of AI and digital tool adoption, whereas teachers with bachelor's, high school, or technical education backgrounds exhibit greater variability in their perceptions. However, the results also indicate that adequate training programs can bridge the gap, enabling educators with lower academic degrees to rate virtual education more positively if they receive proper institutional support.

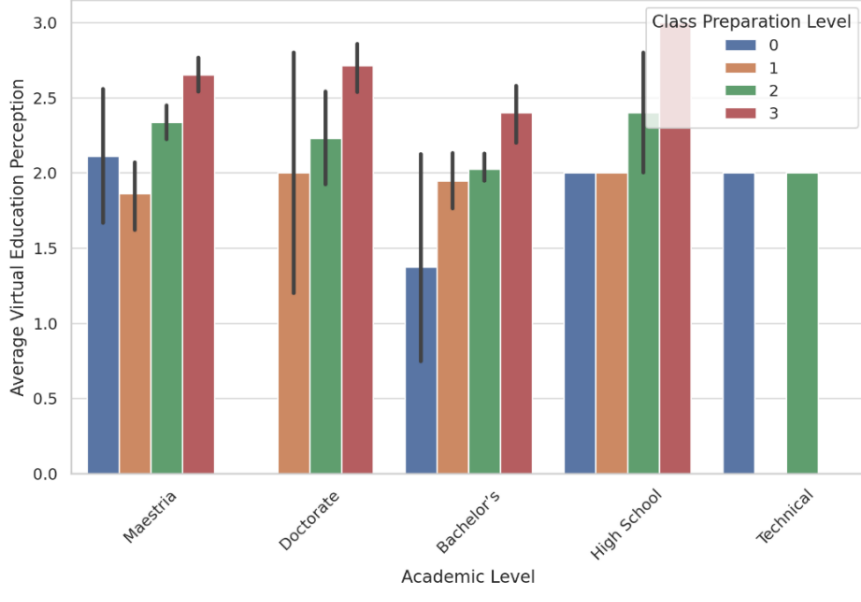

Figure 9: Perception of Virtual Education by Academic Level and Class Preparation

Beyond education, AI adoption in the workplace remains a challenge in Latin America, as illustrated in Figure 10. Panama and Argentina show the lowest AI adoption rates, despite 97% of respondents recognizing AI's value. The data suggests that while awareness of AI benefits is high, the lack of infrastructure, policies, and training programs inhibits its widespread implementation. This trend reinforces the need for coordinated institutional efforts to develop AI literacy and ensure that both educators and professionals receive the necessary training to fully integrate AI into their work and teaching environments.

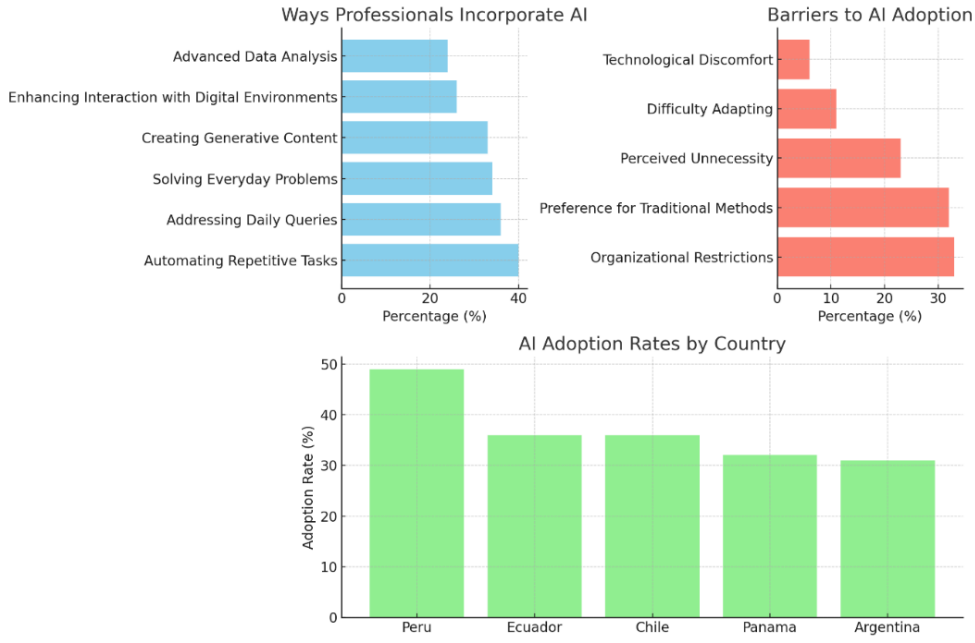

Figure 10: AI usage in the workplace by country in Latin America

The integration of artificial intelligence (AI) into professional tasks is transforming workplace efficiency, with 40% of professionals utilizing AI for automating repetitive tasks, 36% employing it for quick access to information, and 34% leveraging it to solve everyday problems, according to a study by Konzerta. Despite these advantages, barriers such as organizational restrictions (33%) and a preference for traditional methods (32%) hinder broader adoption. AI adoption rates also vary by region, with Peru leading at 49%, while Panama and Argentina report the lowest at 32% and 31%, respectively. Other studies, such as research conducted by the World Economic Forum (2023) and McKinsey & Company (2022), highlight similar trends, emphasizing that AI-driven training enhances workforce adaptability and decision-making. Furthermore, mathematical proficiency plays a crucial role in maximizing AI's potential, as it underpins data analysis, algorithmic understanding, and problem-solving skills—key competencies for modern professionals. Addressing AI adoption challenges through targeted training in mathematics and digital skills could significantly improve professional development and productivity across industries.

Institutional support and technological access are decisive factors in determining the effectiveness of AI adoption and virtual education. The findings suggest that while many

educators feel prepared for virtual instruction, there remain gaps in training, technological access, and policy implementation that need to be addressed. By prioritizing professional development, infrastructure investment, and regional digital equity, institutions can enhance teachers' capacity to integrate AI into mathematics education, ultimately improving learning outcomes and ensuring sustainable AI integration in the educational sector.

Limited access and uneven institutional support may impact the feasibility of sustained integration of AI tools, reinforcing the need to align training efforts with available infrastructure and support systems.

Discussion

This study reinforces the importance of institutional support, professional development, and equitable technological access in advancing AI adoption in mathematics education across Latin America. Consistent with previous research (García-Benítez & Ruvalcaba-Gómez, 2021; Marques-Castelo-Branco-Biondi & Kemmer-Cernev, 2023), findings highlight that teachers in institutions with structured AI training and digital infrastructure demonstrate higher confidence in integrating AI into their instructional practices. However, significant disparities persist between urban and rural regions, as schools in underfunded areas lack access to AI tools, reliable internet, and ongoing training programs. These disparities align with studies showing that institutional investment and government-backed digital policies directly impact the scalability and effectiveness of AI-driven learning environments (Banco Mundial, 2025; Profuturo & OEI, 2024).

Contrasting with these findings, Aggarwal, Sharma, and Saxena (2023) argue that AI adoption in education also depends on cultural acceptance and the long-term sustainability of digital infrastructure. While this study reaffirms the need for clear regulatory frameworks for AI implementation, these authors emphasize that successful adoption also requires a holistic approach encompassing teacher training and adaptive teaching strategies.

The evaluation of teaching and learning processes in mathematics teacher education requires theoretical models capable of articulating multiple dimensions of professional knowledge. In response to this need, we propose an integrative analytical framework that brings together four well-established approaches in mathematics education research: the Onto-Semiotic Approach (OSA) (Godino, Batanero, & Font, 2007), the Didactic-Mathematical Knowledge and Competences (DMKC) model (Font, Batanero, & Godino, 2018), the Technological Pedagogical Content Knowledge model extended with contextual components (TPACK-XK) (Mishra, 2019), and the Theory of Instrumental Genesis (TIG) (Artigue, 2002; Trouche, 2004).

Each framework contributes specific analytical tools: OSA examines the didactical suitability of the mathematical meanings promoted in instruction; DMKC focuses on the professional competencies mobilized by teachers; TPACK-XK integrates technological knowledge with pedagogical and contextual dimensions; and TIG explains how technological artifacts become instruments through processes of instrumentalization and instrumentation.

These frameworks are articulated through the six dimensions of didactical suitability proposed by OSA—epistemic, cognitive, interactional, mediational, emotional, and ecological—which serve as points of connection. This structure enables correspondences between the components of DMKC, the dimensions of TPACK-XK, and the appropriation mechanisms described in TIG (Suárez-Restrepo & Castro-Gordillo, 2017). The resulting model offers a coherent and situated lens to analyze teaching practices in technology-mediated environments. Recent studies

reinforce the relevance of this articulation. Morales-López, Breda, and Font (2024) demonstrate that integrating technological and educational models fosters deep reflection and meaningful learning experiences in initial teacher education. Complementarily, Sol, Ledezma, Sánchez, and Font (2025) show how practical argumentation in professional communities helps identify tensions between suitability criteria, which is essential for informed instructional decision-making. Likewise, Morales-López and Font (2024) emphasize the importance of confronting preservice teachers with real-world digital teaching scenarios as a way to strengthen their capacity for analysis and adaptation in complex educational contexts.

This study also corroborates previous findings that gender disparities influence AI adoption in education. Female educators express greater concern about students' digital competencies, whereas male educators report higher confidence in their own AI skills, aligning with trends identified by Huincahue and Muñoz (2024). Addressing these disparities requires gender-sensitive AI training programs that empower all educators with equitable access to digital literacy development. Additionally, Bhatt and Muduli (2023) suggest that AI can serve as an effective tool for personalizing instruction based on individual teacher and student needs, which could help bridge these gender gaps if adequate training strategies and mentorship programs are implemented.

The AI adoption gap between countries is also evident in this study, echoing prior reports that economic development and national AI strategies determine the pace of technological integration in education (Salas-Pilco & Yang, 2022; ITU, 2022). While countries like Chile and Mexico have advanced AI-enhanced learning systems, others, including Panama and Argentina, still struggle with AI implementation, despite strong recognition of AI's potential benefits (Brochado, 2023; Flores-Vivar & García-Peñalvo, 2023). In this regard, Aldowah, Al-Samarraie, and Fauzy (2019) propose that educational data mining and learning analytics can provide valuable insights to guide AI adoption policies, allowing governments and institutions to optimize resources and design more effective integration strategies.

Furthermore, this study highlights the necessity of pedagogical tools tailored to facilitate AI adoption in mathematics instruction. In this context, Cahyono, Sukestiyarno, and Asikin (2020) demonstrated that augmented reality programs can enhance the understanding of complex mathematical models, while Bozkurt et al. (2021) argue that the combination of AI and adaptive learning has the potential to transform the educational landscape by enabling more personalized and efficient instruction.

Finally, existing literature underscores the importance of AI-driven chatbots in supporting teachers and enhancing student engagement. Recent research, such as Bayounes, Saâdi, and Hamroun (2023) on NajahniBot, and Calonge, Smail, and Kamalov (2023) on AI chatbots in statistics and calculus, demonstrates that these tools can provide immediate feedback and personalize learning experiences. However, Chen, Chen, and Lin (2020) caution that the effectiveness of these solutions depends on their pedagogical design and adaptability to specific educational contexts, a challenge still unresolved in many developing countries.

Conclusion

This study provides evidence of the factors influencing AI adoption in mathematics education in Latin America, emphasizing the importance of institutional support, equitable technological access, gender inclusivity, and clear policy frameworks. The reviewed literature suggests that AI can be a transformative tool in education, but its effective adoption requires sustainable

investments, continuous professional development, and strategies adapted to the specific needs of each educational context.

Future AI-based educational interventions must prioritize targeted teacher training programs that bridge regional and gender gaps, ensuring that all educators are equipped with the necessary skills to integrate AI tools effectively into their instruction. Additionally, governments and institutions should collaborate in developing regulatory policies that promote ethical AI use and enhance the accessibility of digital resources, particularly in underprivileged regions.

Ultimately, the successful implementation of AI in Mathematics Education will depend on a balanced approach that combines technological advancements with pedagogical innovation. By fostering a culture of digital literacy, inclusivity, and institutional commitment, Latin American countries can maximize the potential of AI to enhance student learning outcomes and empower educators in the digital age.

Recommendations

1. Expand AI Training and Digital Competency Programs

- Develop regional AI training initiatives tailored to the specific digital literacy gaps of educators and students in underserved areas.
- Promote hands-on AI workshops and continuous professional development opportunities to improve teacher confidence and efficiency in AI-enhanced classrooms.

2. Ensure Equitable Technological Access Across Regions

- Governments and educational institutions should prioritize digital infrastructure investments, ensuring that schools in rural and lower-income provinces receive AI resources, high-speed internet, and digital learning tools.
- Public-private partnerships should be encouraged to bridge the AI adoption divide and provide educators with the necessary digital tools.

3. Develop Inclusive and Gender-Sensitive AI Strategies

- Implement customized AI training programs that address gender-specific concerns and empower female educators to confidently integrate AI into teaching.
- Encourage mentorship programs that foster collaborative learning and help reduce gender disparities in AI adoption.

By implementing these recommendations, Latin American educational systems can enhance AI adoption, foster digital inclusivity, and create sustainable learning environments that empower both educators and students. Future research should focus on longitudinal studies assessing the impact of AI-based interventions on student learning outcomes and evaluating policy frameworks for sustainable AI implementation in Latin American education systems.

Acknowledgments

The first author gratefully acknowledges the support of the National Secretariat of Science, Technology and Innovation (SENACYT) of Panama, as a doctoral student funded through its advanced training programs. The academic and scientific guidance of the corresponding author is also recognized, as she serves as a full professor at the University of Panama and doctoral advisor within the framework of the doctoral program carried out at the University of Barcelona.

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