Neutrosophic Sets and Systems, {Special Issue: Artificial Intelligence, Neutrosophy, and Latin American Worldviews: Toward a Sustainable Future (Workshop – March 18–21, 2025, Universidad Tecnológica de El Salvador, San Salvador, El Salvador)}, Vol. 84, 2025

University of New Mexico

Structural conditions and ethical dilemmas of the integration of Artificial Intelligence in Latin American Public Higher Education

Paola Elizabeth Cortez Clavijo [1*], Marjorie Alexandra Coronel Suárez [2], Lourdes Hilda Ortega Maldonado [3], Félix Javier Rosales Borbor [4], Cynthia Nataly Espíndola Vásquez[5], María Magdalena Gonzabay Espinoza [6], Mónica Karina Jaramillo Infante [7], Xavier Eduardo Espíndola Vásquez [8]

[1] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. pcortez@upse.edu.ec
[2] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. mcoronel@upse.edu.ec
[3] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. lortega@upse.edu.ec
[4] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. frosales@upse.edu.ec
[5] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. cespindola@upse.edu.ec
[6] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. mgonzabay@upse.edu.ec
[7] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. mjaramillo@upse.edu.ec
[8] Universidad Estatal Península de Santa Elena. La Libertad. Ecuador. eduardov0507@gmail.com

Abstract: This study, using a neutrosophic approach, evaluates the integration of artificial intelligence in Latin American public higher education, focusing on the perceptions and ethical dilemmas of university stakeholders. Two groups of students in a scientific writing course were compared: one that used AI tools during the writing process and another that employed traditional methods. The results show that the use of AI favors active participation and the final quality of the essays, although it does not significantly impact prior knowledge or argumentative depth. The intervention reveals both benefits, such as greater engagement and improved performance, and ethical tensions related to privacy, equity, and transparency. The analysis highlights that the adoption of AI in educational contexts requires policies and practices that promote inclusion, ethics, and social justice. The results suggest that the integration of AI can enhance educational quality and participation, but always within a framework of critical reflection that ensures respect for ethical principles and equity in Latin American universities.

Keywords: Artificial Intelligence; Higher Education; Neutrosophic Logic, Ethics

1. Introduction

The integration of artificial intelligence (AI) into Latin American public higher education constitutes one of the most significant transformations in contemporary education. Far from being solely about the incorporation of technological tools, this process entails a profound reconfiguration of pedagogical practices, academic management models, and the forms of interaction between students, faculty, and knowledge. In an environment characterized by structural limitations, digital divides, and growing demands for inclusion and quality, public universities face the challenge of adopting smart technologies in an ethical, relevant, and sustainable manner, without undermining their founding principles of equity, critical thinking, and the democratization of knowledge.

AI-based technologies have the potential to significantly improve the educational experience by personalizing learning, automating administrative processes, predicting academic performance, recommending learning paths, and optimizing teaching strategies [1]. These capabilities, supported by

massive data processing and machine learning techniques, have been widely explored by the emerging field of Artificial Intelligence in Education (AIeD), which has demonstrated positive impacts in virtual and blended learning environments [2]. The possibility of offering adaptive training itineraries, immediate feedback, and instructional strategies tailored to the student's profile marks a new educational paradigm focused on personalization and learning efficiency [3].

However, this progress is not without ethical, social, and cultural tensions. In Latin American public universities, the implementation of AI faces multiple dilemmas, from the lack of adequate technological infrastructure and limited digital literacy training for faculty to legitimate concerns about data privacy, algorithmic bias, the dehumanization of teaching, job insecurity, and the absence of clear regulatory frameworks. These problems are exacerbated in contexts marked by social inequality and inequity in access to digital resources, which can lead to new mechanisms of exclusion within the educational system itself.

In this context, it is essential to overcome technocratic or deterministic approaches that consider AI as a panacea and move towards a critical and situated perspective, capable of considering the structural conditions and ethical dilemmas associated with its integration into public higher education institutions [4]. The creation of smart campuses, the use of educational chatbots, automated tutoring systems, and the algorithmic evaluation of teacher-student performance are just some of the expressions of this phenomenon that require analysis based on pedagogical, epistemic, and social justice criteria.

Likewise, the adoption of active learning environments mediated by AI represents a superior alternative to the traditional model focused on lectures, where the student plays a passive role [5]. AI enables the analysis of student-generated data to identify patterns and individual needs, enabling more informed, consistent, and equitable decision-making in teaching and learning processes. However, these opportunities must be accompanied by ethical frameworks that guide the development and use of these technologies for the common good.

This study aims to analyze how ethical, technological, and institutional constraints influence the integration of artificial intelligence in Latin American public universities, and what their implications are for educational quality and inclusion. Through a neutrosophic approach, we seek to understand the complexity of the phenomenon from multiple levels of uncertainty, contradiction, and ambiguity, considering the perceptions of different university stakeholders and exploring implementation scenarios that promote a more inclusive, critical, and contextualized educational transformation.

2. Preliminaries

The digital transformation driven by emerging technologies, especially artificial intelligence (AI), has profoundly reconfigured the dynamics of higher education institutions (HEIs) globally. In Latin America, this phenomenon has highlighted both the opportunities and the structural, ethical, and institutional tensions that arise when integrating these tools into public contexts. AI, applied to higher education, is not limited to automating administrative processes or personalizing learning content, but also represents a strategic tool for decision-making, academic management, and improving student performance, especially when combined with technologies such as the Internet of Things (IoT), cloud computing, big data analytics, and smart environments [6].

At the heart of the debate on AI in higher education is also the development of learning and the transformation of the roles of its key stakeholders: students and teachers. Active learning, driven by digital technologies, shifts the traditional lecture-centered model toward scenarios where the student takes on a leading role. This change is not merely technical but profoundly pedagogical and ethical, as it requires redefining learning objectives, assessment methods, and power relations in the classroom. Learning theories—behaviorism, cognitivism, and constructivism—allow us to understand this

phenomenon from a solid conceptual foundation, guiding pedagogical strategies toward greater personalization, motivation, and effectiveness in the educational process [7].

In this context, artificial intelligence becomes a powerful ally in identifying students' learning patterns and adapting content to their particular styles and needs. Through algorithms capable of emulating human cognitive processes, AI can detect at-risk students, generate personalized learning paths, and optimize knowledge management. However, these potentialities must be weighed against relevant ethical dilemmas: algorithmic bias, constant surveillance, loss of educational autonomy, and digital inequality. It is therefore essential that its implementation be accompanied by appropriate regulatory frameworks, critical digital literacy processes, and an ethical commitment from institutions.

2.1 Structural conditions and ethical dilemmas of the integration of artificial intelligence in Latin American public higher education

The incorporation of artificial intelligence into Latin American public higher education represents a large-scale phenomenon that invites profound reflection on its structural conditions and inherent ethical dilemmas [7]. In structural terms, the main challenges focus on technological infrastructure limitations, the availability and quality of specialized human resources, and unequal access to technology. While some institutions have made progress in adopting digital platforms and AI tools, significant gaps persist that limit equity in the implementation of these resources, especially in rural areas and regions with less investment in educational infrastructure. The lack of clear institutional policies and specific regulatory frameworks also creates an environment of uncertainty that affects the planning, sustainability, and effective integration of these technologies [8].

From an ethical perspective, the integration of AI into higher education raises profound dilemmas related to privacy, data protection, transparency in algorithms, and academic autonomy. The massive collection of student data to feed prediction models or personalize learning raises concerns regarding the protection of sensitive information and informed consent. Furthermore, the use of automated systems to evaluate performance, provide feedback, or detect unethical behavior demands transparency and explainability, aspects that are not yet fully guaranteed in many AI platforms. On the other hand, debates arise about the impact of these technologies on the autonomy of teachers and students, who could become dependent on algorithmic decisions that sometimes lack adequate ethical or contextual interpretation [9].

The opportunities offered by AI in Latin American higher education are vast and include personalized learning, support for continuous assessment, automation of administrative tasks, and optimization of academic processes. However, to harness these advantages ethically and responsibly, it is essential to strengthen structural conditions through investment in infrastructure, training, and robust regulatory frameworks [10]. It is equally important to promote an ethical culture that prioritizes the protection of rights, encourages transparency in algorithms, and ensures the fair use of data. Responsible governance of AI in education must be a priority, coordinating the work of educational institutions, regulatory bodies, and the academic community at large with concrete proposals that ensure equity, ethics, and the active participation of all stakeholders.

Table 1. Structural and ethical conditions for the integration of AI in Higher Education.

Associated elements	Opportunities	Improvement proposals
Technological infrastructure	It facilitates access to digital platforms and online resources, expanding educational coverage.	Invest in technological infrastructure in rural areas and disadvantaged regions.

Associated elements	Opportunities	Improvement proposals
Training of teaching and administrative staff	It promotes the development of digital skills and knowledge of AI ethics.	Implement ongoing training programs in educational technologies and digital ethics.
Institutional policies and regulatory frameworks	It provides a framework for the responsible and regulated integration of AI in educational contexts.	Create and update specific regulations governing data protection, privacy, and the ethical use of AI.
Access and equity in the use of technology	It reduces social and geographic gaps in access to digitalized education.	Design digital inclusion policies and technology subsidy programs for vulnerable students.
Privacy and data protection	Ensures the confidentiality and security of student and teacher information.	Implement robust data protection systems and promote a culture of informed consent.
Transparency and explainability of algorithms	Fosters trust in AI tools and their ethical use.	Develop explainable algorithms and promote independent audits of AI systems.
Academic and teaching autonomy	Allows educational stakeholders to maintain control over pedagogical processes.	Establish clear limits on automation and ensure the active participation of teachers in decision-making.
Participation and ethical dialogue	Promotes the use of AI that respects human rights and values.	Create specialized AI ethics committees and promote open and participatory debates within institutions.
Financial resources and financing	They enable the sustained acquisition and maintenance of AI technologies.	Seek international partnerships, public and private funding, and promote applied research in educational AI.
Institutional culture and ethical awareness	They foster a responsible and proactive attitude toward the ethical dilemmas of AI.	Implement awareness-raising, ethics-based, and digital rights training campaigns throughout the educational community.

To carry out the analysis of the structural conditions and ethical dilemmas of the integration of AI in Latin American public higher education, the present research uses Neutrosophic Logic, proposed by Florentin Smarandache [11], which allows analyzing different variables and actors with a degree of uncertainty or ambiguity.

2.2. Definition of Neutrosophic Logic

Neutrosophic Logic is a formal system of fuzzy logic that allows for the handling of information with degrees of truth, falsity, and neutrality, reflecting uncertainty, doubt, or ambiguity in the data. Unlike classical binary logic, it allows for intermediate values that represent states of bias in the evaluation of complex phenomena [12].

In this research, Neutrosophic Logic is applied to evaluate perceptions and conditions related to the integration of AI in Latin American public higher education, considering that these aspects contain degrees of uncertainty. Opinions, conditions, and dilemmas are translated into neutrosophic values, allowing for inferences that integrate different levels of certainty. This approach more accurately reflects reality, facilitating multivariate analysis in contexts of incomplete or ambiguous information, and promoting decisions and policies more tailored to the complexity of the scenario.

The use of Neutrosophic Logic facilitates the integration of fragmented or partial information, offering more reliable and representative inferences of reality. Furthermore, it fosters a flexible and humanized analysis that reflects the complexity and multiplicity of perspectives, consolidating more responsible and contextualized decisions and proposals for improvement [13].

3. Materials and Methods

The objective of this research was to apply a neutrosophic analysis model to evaluate the perceptions and ethical dilemmas surrounding the use of Artificial Intelligence (AI) in Latin American Public Higher Education. The course "Writing and Publishing Scientific Articles," taught in a blended learning environment at the Peninsula of Santa Elena State University, was used as a reference for this analysis. Using this course as a case study, the aim is to generate relevant information to guide the critical, ethical, and structurally viable adoption of this technology. Furthermore, the research empirically analyzed how students engage with AI tools during their training processes and how they perceive their impact on aspects such as academic autonomy, research ethics, and educational quality. The questions that guided the research were:

RQ 1. To what extent did the groups (experimental and control) differ in terms of acceptance and trust in the use of AI in scientific research processes?

RQ 2. To what extent did the groups differ in their ability to identify ethical dilemmas associated with the use of AI in higher education?

RQ 3. To what extent did the groups differ in terms of their perceptions of the role of AI in educational equity, quality, and innovation?

3.1 Research context and participants

The study was conducted in a six-week online course entitled "Writing and Publishing Scientific Articles" for graduate students at the Peninsula of Santa Elena State University, taught during the second academic semester of 2024. The course aimed to strengthen students' research skills by integrating critical analysis of AI-based tools for academic writing, data analysis, and bibliographic review. Classes were held twice a week, each lasting 100 minutes. The platform used for the online component was Moodle, complemented by synchronous sessions via Zoom.

A total of 48 graduate students participated, distributed across three master's programs (Education, Law, and Public Management). Two groups were formed: a control group (22 students divided into four groups) and an experimental group (26 students divided into five groups). Both groups participated in the same academic activities, except that the experimental group received automated feedback based on neutrosophic predictions about their performance. [15,16]

3.2 Instructional procedure

With the exception of the introductory week and the final presentation week, the facilitator (the second author of this research) structured the sessions between Weeks 2 and 5 into three components: theoretical lectures, collaborative group discussion, and guided writing of scientific articles.

- Theoretical lectures: Key concepts on artificial intelligence in higher education, contemporary ethical dilemmas, principles of scientific integrity, and standards for academic publishing were addressed.
- Collaborative discussion: The groups addressed practical cases related to the use of AI in research processes (e.g., the use of ChatGPT or bibliographic analysis software), reflecting on the ethical, legal, and pedagogical implications. Discussions took place in group forums within Moodle. The facilitator provided guiding questions but did not directly intervene in the discussions.
- Collaborative writing: Each group developed an academic essay on an ethical dilemma related to the use of AI in the university setting. This activity was divided into three partial submissions (one per week between Week 2 and Week 4), which were provided feedback to consolidate the final document in Week 5.

In Week 6, the groups presented their final work in oral presentations evaluated by a faculty panel.

3.3 Neutrosophic Model of Ethical Assessment and Learning

A. Input variables

The model includes four input variables, all modeled as Single-Valued Neutrosophic Numbers (SVNN), with their corresponding triplets (T, I, F), where:

- $T \in [0,1]$: Degree of perceived truth or certainty.
- $I \in [0,1]$: Degree of uncertainty or ambiguity.
- $F \in [0,1]$: Degree of perceived falsity or disagreement.

The sum is not restricted to $T + I + F = 1$, which allows for more realistic handling of uncertainty, an essential feature in educational and ethical contexts.

B. Formal definition of variables

1. Prior knowledge about AI: $K_p = (T_k, I_k, F_k)$
   Where:

$$T_k = \frac{N_{correct\ concepts}}{N_{total\ concepts}} \tag{1}$$

$$I_k = 1 - |T_k - F_k| \tag{2}$$

$$F_k = \frac{N_{conceptual\ errors}}{N_{total\ concepts}} \tag{3}$$

2. Participation in collaborative discussions: $P_d = (T_p, I_p, F_p)$
   Where:

$$T_p = \frac{N_{meaningful\ messages}}{N_{total\ interventions}} \tag{4}$$

$$I_p = 1 - \left|T_p - F_p\right| \tag{5}$$

$$F_p = \frac{N_{irrelevant\ messages}}{N_{total\ interventions}} \tag{6}$$

3. Depth of argument on ethical dilemmas: $D_a = (T_d, I_d, F_d)$
   Where:

$$T_d = \frac{N_{valid\ arguments}}{N_{total\ arguments}} \tag{7}$$

$$I_d = 1 - |T_d - F_d| \tag{8}$$

$$F_d = \frac{N_{fallacies\ or\ argumentative\ errors}}{N_{total\ arguments}} \tag{9}$$

4. Scientific writing quality (final essay): $R_c = (T_r, I_r, F_r)$
   Where:

$$T_r = \frac{Format\ score + Coherence\ score + Originality\ score}{Maximum\ score} \tag{10}$$

$$I_r = 1 - |T_r - F_r| \tag{11}$$

$$F_r = \frac{Format\ errors + Source\ errors}{Maximum\ score} \tag{12}$$

C. Global composition: effectiveness of ethical learning

$$E_l = w_1 \cdot K_p + w_2 \cdot P_d + w_3 \cdot D_a + w_4 \cdot R_c \tag{13}$$

The neutrosophic evaluation $E = (T_e, I_e, F_e)$ is calculated as the weighted combination of each attribute:

$$T_e = \sum_{i=1}^{n} w_i \cdot T_i$$
$$I_e = \sum_{i=1}^{n} w_i \cdot I_i \tag{14}$$
$$F_e = \sum_{i=1}^{n} w_i \cdot F_i$$

Where the weights w_1, w_2, w_3 and w_4 represent the relative importance of each component in the final evaluation. The weights satisfy: $w_1 + w_2 + w_3 + w_4 = 1$ and $w_i \in [0,1]$. The weights w_i were established through expert analysis using the Neutrosophic Analytic Hierarchy Process (Neutrosophic AHP) technique. A pairwise comparison matrix $M = [a_{ij}]$, was constructed, where:

a_{ij} =the relative preference of variable i over variable j.

For example, if argumentative depth was considered 3 times more important than participation: $a_{D_a,P_d} = 3$, $a_{D_a,P_d} = \frac{1}{3}$, then the matrix is normalized, and the priority vector is obtained using:

$$w_i = \frac{\sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}}}{n} \tag{15}$$

This is done for each row of the normalized matrix. Consistency is checked using:

$CR = \frac{CI}{RI}$, $I = \frac{\lambda_{max} - n}{n-1}$, where $CR < 0.1$ indicates acceptable consistency.

D. Interpretation of the Results

The neutrosophic model evaluates the ethical and academic effectiveness of the AI-powered learning process in public higher education, based on a case study. The final value $E_l = (T_e, I_e, F_e)$ represents the neutrosophic perception of the ethical and academic effectiveness of each student's learning. This result can be interpreted as:

- T_e close to 1: Degree of positive contribution to learning.
- High I_e: Degree of ethical/academic ambiguity or uncertainty.
- High F_e: Signs of rejection or ethical/academic limitations of the process. Degree of negative impact.

4. Results

To empirically analyze the perceptions, opportunities, and ethical dilemmas surrounding the integration of artificial intelligence (AI) in Latin American public higher education, an intervention was designed based on an academic performance prediction model grounded in Neutrosophic Logic. This intervention was applied in the course "Writing and Publishing Scientific Articles," taught for six weeks online to graduate students at the Peninsula of Santa Elena State University. The experience sought to evaluate the effects of the use of AI and learning analytics (LA) on student engagement, performance, and perceptions through a quasi-experimental approach with two distinct groups (experimental and control).

4.1 Research intervention

The intervention consisted of comparing the impact of the integration of artificial intelligence tools on the students' scientific article writing process. The control group wrote their article using traditional methodologies, conducting conventional bibliographic searches, synthesizing information manually, and representing the data through graphs and statistical analysis without advanced AI support. The experimental group, on the other hand, utilized the various AI tools available during the course, such as text generators, idea organization assistants, data analysis algorithms, and automated visualization, which they actively used to structure and write their scientific article. These tools facilitated the integration of information, the analysis of results, and the generation of graphs, improving the quality and depth of the final work. The variables analyzed to evaluate the effects of AI integration included:

1. Level of prior knowledge about the use of digital tools and AI.
2. Level of participation in collaborative discussions.
3. Depth of analysis and argumentation in the article.
4. Procedural quality in the structuring and presentation of the scientific article.

Students in the experimental group visualized their own performance, as well as that of their peers, using graphs and charts generated on the Moodle platform. Weekly feedback included individualized suggestions for improvement, both from a technical and ethical perspective. This approach allowed not only for a critical understanding of the impact of AI, but also for a deeper reflection on its responsible integration into higher education.

Table 2. Variables considered

Variable	Description	Symbol	Type
Prior knowledge	Diagnostic assessment at the beginning of the course	K_p	input
Frequency of participation	Number of weekly forum contributions	P_d	input
Depth of discussion	Level of critical analysis (expert coding)	D_a	input
Procedural quality	Quality of weekly and final deliverables	R_c	input
Final evaluation	Final course assessment	E_l	expected output

Each input variable is represented as a neutrosophic triplet: $x_i = (T_i, I_i, F_i)$. Taking one of the students in the case study as an example, for the Prior Knowledge variable K_p, would be:

$$K_p = (0.8,0.1,0.1)$$

Where:

T_i: degree of truth (high level).

I_i: degree of indeterminacy (uncertainty in measurement).

F_i: degree of falsity (absence of knowledge).

The weights assigned to each variable (by expert analysis) would be as follows:

$w_{K_p} = 0.25, \quad w_{P_d} = 0.20, \quad w_{D_a} = 0.25, \quad w_{R_c} = 0.30$

The neutrosophic evaluation is calculated according to equation (13). Continuing with the same example, the neutrosophic triplet for a student in the experimental group is defined as follows:

K_p: (0.8, 0.1, 0.1); P_d: (0.7, 0.2, 0.1); D_a: (0.6, 0.3, 0.1); R_c: (0.75, 0.2, 0.05)

The calculation is performed according to equation (13), as follows:

Neutrosophic evaluation E_l:

$$T = (0.25)(0.8) + (0.20)(0.7) + (0.25)(0.6) + (0.30)(0.75) = 0.7125$$
$$I = (0.25)(0.1) + (0.20)(0.2) + (0.25)(0.3) + (0.30)(0.2) = 0.2075$$
$$F = (0.25)(0.1) + (0.20)(0.1) + (0.25)(0.1) + (0.30)(0.05) = 0.0875$$

$$E_l = (0.7125, 0.2075, 0.0875)$$

For this specific case, the results are interpreted as follows:

- There is 71% positive effectiveness (T) in the ethical and academic use of AI in learning.
- There is 20% ambiguity or uncertainty about its impact.
- Only 8% of potential negative effects are present, suggesting a favorable implementation but with ethical aspects to monitor.

4.2. General results of the case study

The results obtained from applying the neutrosophic model described above are presented below. The analysis was organized into two parts: first, a description of the results by group (experimental and control), and second, a comparison between the two groups in relation to the key study variables.

4.2.1. Results of the Experimental Group

Table 4 shows the average values of the variables evaluated using neutrosophic triplets for the experimental group:

Table 4. Average neutrosophic values for the experimental group (n=26)

Variable	T (Truth)	I (Indeterminacy)	F (Falsehood)
Prior knowledge (K_p)	0.73	0.18	0.09
Frequency of participation (P_d)	0.81	0.12	0.07
Depth of discussion (D_a)	0.76	0.15	0.09
Procedural quality (R_c)	0.79	0.14	0.07
Final evaluation (E_l)	0.77	0.15	0.08

These results indicate that students in the experimental group showed a high positive contribution (T = 0.77), moderate indeterminacy (I = 0.15), and low perceptions of falsehood or disagreement (F = 0.08) regarding the use of AI in the ethical and academic learning process.

4.2.2. Control group results

Table 5 presents the values for the control group:

Table 5. Average neutrosophic values for the control group (n=22)

Variable	T (Truth)	I (Indeterminacy)	F (Falsehood)
Prior knowledge (K_p)	0.68	0.21	0.11
Frequency of participation (P_d)	0.74	0.18	0.08
Depth of discussion (D_a)	0.71	0.19	0.10
Procedural quality (R_c)	0.72	0.20	0.08
Final evaluation (E_l)	0.71	0.20	0.09

Comparatively, the control group had a lower level of truth (T = 0.71) and greater indeterminacy (I = 0.20), suggesting a less structured learning process or greater ethical and academic ambiguity compared to the experimental group.

4.2.3. Comparative Analysis

Table 6 presents the comparative values of the final evaluations (E_l) for both groups.

Table 6. Comparison between the experimental and control groups.

Grupo	T_e (Truth)	I_e (Indeterminacy)	F_e (Falsehood)
Experimental	0.77	0.15	0.08
Control	0.71	0.20	0.09
Difference (Δ)	+0.06	–0.05	–0.01

The experimental group outperformed the control group in terms of positive contribution (ΔT = +0.06) and showed less ambiguity (ΔI = –0.05), suggesting that feedback based on the neutrosophic model had a favorable impact on the structuring of students' ethical and academic thinking. The difference in falsity (ΔF = –0.01) was marginal (Figure 1).

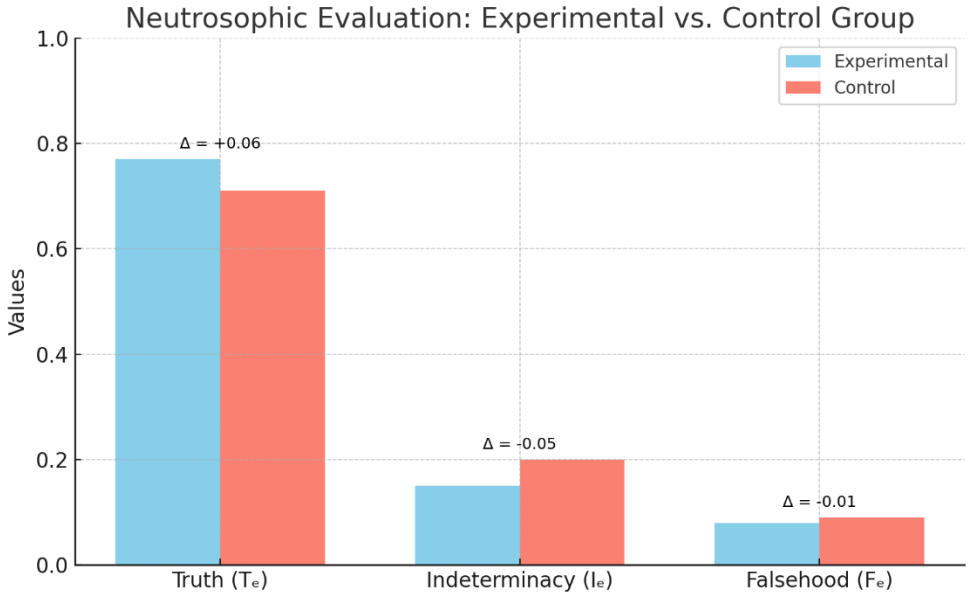

Figure 1. Comparison of truth (T_e), indeterminacy (I_e), and falsehood (F_e) values between the experimental and control groups, including the calculated differences (Δ) for each neutrosophic component.

Additionally, a statistical comparison was performed using t-tests between both conditions to evaluate the variables under analysis, which is summarized in the following table:

Table 7. t-test comparison of the study variables.

Variable	Group	Mean	Std. Dev.	F	p	Comparison
Prior knowledge (K_p)	Control	0.65	1.02	3.21	0.218	
	Experimental	1.12	1.30			
Frequency of participation (P_d)	Control	5.55	8.40	1.90	0.027*	Exp > Control
	Experimental	9.80	10.70			
Depth of discussion (D_a)	Control	3.20	4.75	2.87	0.074	
	Experimental	6.60	8.12			
Procedural quality (R_c)	Control	1.00	1.41	1.60	0.233	
	Experimental	1.85	2.12			
Final evaluation (E_l)	Control	2.80	3.20	2.40	0.038*	Exp > Control
	Experimental	5.50	4.90			

* $p \leq 0.05$

An analysis of the results revealed that the group that used AI tools showed significant improvements in several dimensions. Active participation in the preparation of the article was greater, reflecting a deeper commitment to the research and writing process. The final quality of the article, assessed using rubrics that considered coherence, originality, data analysis, and visual support, was clearly superior in the experimental group, demonstrating that technological assistance contributed to improving the methodological and argumentative quality of the work. Furthermore, students stated that the use of AI facilitated the organization of complex ideas and accelerated processes that, in traditional methods, take more time and effort.

These findings suggest that the incorporation of artificial intelligence tools in higher education can have positive effects on the quality of academic products, the level of participation, and students' perceptions of their learning process. Technology does not replace critical work, but rather complements it, helping students enhance their capabilities and overcome the limitations of conventional methods. The results suggest that integrating AI into university scientific production represents an opportunity to strengthen teaching-learning processes and promote a more innovative and efficient approach to academic training.

4. Discussion

The integration of Artificial Intelligence into higher education, particularly in Latin American contexts, represents a profound transformation of the educational ecosystem, not only from a technological perspective, but also from a structural, pedagogical, and ethical perspective. AIdA allows for the creation of personalized, student-centered learning experiences, which entails a reformulation of the traditional roles of teachers and students: the former as facilitators and strategic mediators, and the latter as protagonists of their educational process.

From this perspective, AI-based tools, such as predictive models of student performance and real-time learning analytics, can significantly improve pedagogical decision-making. These technologies enable continuous feedback, progress monitoring, and early identification of academic risks. In the Latin American context, these functionalities become strategic due to the high dropout rates, inequality, and lack of personalization in public higher education. However, currently implemented AI models tend to

focus more on summative performance rather than on the learning processes themselves, creating gaps in the comprehensive understanding of student development. This is particularly problematic in scenarios where quantitative outcomes are prioritized over students' educational trajectories and social or emotional contexts. Therefore, it is necessary to move toward models that incorporate multimodal analysis and integrated approaches to educational data mining and learning analytics.

In line with these needs, the closed-loop AIEd development cycle, comprised of model creation, optimization, application, and empirical validation, constitutes a crucial paradigmatic framework. This cycle demands a synergy between artificial and human intelligence, highlighting that the cognitive, affective, ethical, and social dimensions of learning cannot be automated or replaced. In this sense, neutrosophic analysis provides a pertinent approach by allowing for the modeling of the uncertainty and indeterminacy that characterize both educational systems and pedagogical decisions involving AI.

Furthermore, this study recognizes that the paradigmatic shift in the integration of AI in higher education must comprise three phases: (1) AI as a guide to the process (student as recipient), (2) AI as a support to the process (student as collaborator), and (3) AI as an empowerer (student as a leader of their learning) [14]. This progression is essential for an ethical and contextualized adoption of technology, especially in Latin American public universities, where structural conditions—infrastructure, data access, and teacher training—still represent significant barriers.

The neutrosophic analysis conducted on the use of AI reveals tensions between the perceived usefulness of these tools and ethical concerns linked to student autonomy, equal access, algorithm transparency, and data privacy. These tensions must be addressed through clear institutional policies, AI ethics training for teachers and researchers, and the development of intelligent platforms based on principles of inclusion and social justice.

However, the results obtained from the implementation of the proposed neutrosophic model suggest that the adoption of AI in higher education has a positive effect on key learning processes, particularly motivation, engagement, and the quality of final products.

5. Conclusions

This research demonstrated that the integration of artificial intelligence (AI) in Latin American public higher education requires not only technological development but also a structured, ethical, and contextualized approach to its implementation. Using the proposed neutrosophic model, it was possible to identify, represent, and analyze the levels of truth, uncertainty, and falsehood in perceptions, decisions, and outcomes linked to the use of AI in complex and diverse educational contexts.

The neutrosophic model allowed for the incorporation of the uncertainty inherent in educational processes, especially with regard to the interpretation of academic data, the evaluation of learning trajectories, and the assessment of institutional conditions for the adoption of technologies. By considering contradictory and incomplete dimensions of the educational phenomenon—such as the tension between automation and autonomy, or between efficiency and equity—the neutrosophic approach proved to be a robust tool for the structural and ethical analysis of AI in higher education. One of the most relevant findings was the model's ability to mathematically represent the ambiguities faced by teachers, students, and university administrators when using intelligent systems. It revealed that while certain elements are perceived as positive (for example, the personalization of learning), other aspects generate uncertainty or rejection (such as algorithmic opacity or the depersonalization of the educational process).

Furthermore, the neutrosophic analysis showed that AI-assisted pedagogical decision-making is more effective when humanistic, ethical, and social criteria are incorporated, rather than based exclusively on performance metrics. In this sense, the proposed model favors a more holistic and critical view of AI, overcoming traditional approaches focused solely on predictive accuracy.

It is concluded that the teaching and learning of the future must be oriented toward the active and reflective integration of AI as a tool for learning analytics, with the aim of organizing, interpreting, and applying educational data in ways that drive informed decision-making, improve learning environments, and effectively contribute to student success. However, the success of this transformation will depend on the design of solid institutional frameworks that promote data sovereignty, teacher training in digital ethics, and the development of inclusive, adaptive, and socially responsible solutions.

Funding: "This research received no external funding"

Conflicts of Interest: "The authors declare no conflict of interest."

References

[1] F. Ouyang, M. Wu, L. Zheng, L. Zhang, and P. Jiao, "Integration of artificial intelligence performance prediction and learning analytics to improve student learning in online engineering course," *International Journal of Educational Technology in Higher Education,* vol. 20, no. 1, pp. 4, 2023.

[2] S. Wang, F. Wang, Z. Zhu, J. Wang, T. Tran, and Z. Du, "Artificial intelligence in education: A systematic literature review," *Expert Systems with Applications,* vol. 252, pp. 124167, 2024.

[3] G.-J. Hwang, H. Xie, B. W. Wah, and D. Gašević, "Vision, challenges, roles and research issues of Artificial Intelligence in Education," Elsevier, 2020, p. 100001.

[4] L. Chen, P. Chen, and Z. Lin, "Artificial intelligence in education: A review," *Ieee Access,* vol. 8, pp. 75264-75278, 2020.

[5] H. R. Amado-Salvatierra, M. Morales-Chan, R. Hernandez-Rizzardini, and M. Rosales, "Exploring educators' perceptions: Artificial intelligence integration in higher education." pp. 1-5.

[6] A. P. Murdan, and R. Halkhoree, "Integration of Artificial Intelligence for educational excellence and innovation in higher education institutions." pp. 1-6.

[7] O. M. Cornelio, A. R. Rodríguez, W. L. S. Álava, P. G. A. Mora, L. M. S. Mera, and B. J. P. Bravo, "La Inteligencia Artificial: desafíos para la educación," *Editorial Internacional Alema*, 2024.

[8] R. F. Z. Campozano, "Impacto de la Inteligencia Artificial en la transformación digital de la Educación," *Serie Científica de la Universidad de las Ciencias Informáticas,* vol. 18, no. 1, pp. 177-192, 2025.

[9] L. Ruiz, and B. M. P. Herrera, "La educación virtual: avanzada tendencia en el desarrollo de la educación a distancia," *Serie Científica de la Universidad de las Ciencias Informáticas,* vol. 13, no. 3, pp. 1-10, 2020.

[10] N. W. Guagchinga Chicaiza, E. C. Borja Salazar, and E. M. Pacheco Pruna, "La Inteligencia Artificial en el aprendizaje del idioma inglés para estudiantes de Nivel Pre-Intermedio (B1)," *Serie Científica de la Universidad de las Ciencias Informáticas,* vol. 17, no. 11, pp. 45-54, 2024.

[11] O. M. Cornelio, and B. B. Fonseca, "Neutrosophic computational model for identifying trends in scientific articles using Natural Language Processing," *Neutrosophic Sets and Systems,* vol. 84, pp. 134-145, 2025.

[12] S. O. Prado, A. H. E. Estela, M. C. V. Villegas, V. V. Gonzales, E. F. Q. Alarcón, and D. M. M. Fernández, "Análisis de la relación entre las estrategias metacognitivas y la actitud científica en estudiantes de la

Facultad de Educación a través de uso de la n-aléctica neutrosófica," *Serie Científica de la Universidad de las Ciencias Informáticas,* vol. 18, no. 2, pp. 237-253, 2025.

[13] N. B. Hernández, J. L. M. Cando, and M. Á. G. Llerena, "Dinámicas de identidad de género en la educación a través de una investigación neutrosófica," *Investigación Operacional,* vol. 45, no. 4, 2024.

[14] F. d. R. Miranda Flores de Valgas, and A. Rodríguez Rodríguez, "Uso adecuado de la inteligencia artificial en el Proceso Enseñanza-Aprendizaje de los estudiantes universitarios," *Serie Científica de la Universidad de las Ciencias Informáticas,* vol. 17, no. 5, pp. 131-145, 2024.

[15] Batista-Barallobre, A. R. (2024). Análisis de la Desigualdad de Género en la Representación Femenina en Órganos de Poder: Influencia de las Prácticas Socioculturales y Normativas. Neutrosophic Computing and Machine Learning. ISSN 2574-1101, 34, 328-335.

[16] Teruel, K.P., Cedeno, J.C., Gavilanez, H.L., & Diaz, C.B. "A framework for selecting cloud computing services based on consensus under single valued neutrosophic numbers," Neutrosophic Sets and Systems, Vol. 22, No. 1, pp. 4, 2018.

Received: December 27, 2024. Accepted: April 8, 2025.