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Editorial

Uso de la inteligencia artificial en la educación superior

La irrupción de la inteligencia artificial (IA) en la educación superior constituye uno de los fenómenos más disruptivos del ecosistema universitario contemporáneo. Herramientas de inteligencia artificial generativa, sistemas de analítica de aprendizaje, asistentes virtuales y plataformas adaptativas están modificando progresivamente la forma en que se produce, distribuye y evalúa el conocimiento. En este nuevo escenario, el profesorado universitario enfrenta el desafío de redefinir su rol pedagógico, investigativo y ético en un contexto donde la tecnología no solo apoya el proceso educativo, sino que también participa activamente en la generación de contenidos, la resolución de problemas y la toma de decisiones.

La incorporación de la IA en la educación superior abre importantes oportunidades para enriquecer el proceso de aprendizaje-enseñanza. Entre ellas destacan la personalización del aprendizaje, el acceso ampliado a recursos educativos, el apoyo a la escritura académica y la optimización de tareas docentes como la retroalimentación o el análisis de datos de aprendizaje. Sin embargo, estas potencialidades también plantean interrogantes profundas sobre el sentido de la formación universitaria, la naturaleza del conocimiento académico y las competencias que deberán desarrollar tanto estudiantes como docentes en un entorno cada vez más mediado por algoritmos.

Uno de los principales desafíos para el profesorado radica en la alfabetización en inteligencia artificial. No se trata únicamente de aprender a utilizar herramientas tecnológicas, sino de comprender sus fundamentos, alcances y limitaciones. La alfabetización en IA implica desarrollar una comprensión crítica sobre cómo funcionan los sistemas algorítmicos, cómo se generan los datos que alimentan estos modelos y cuáles son los sesgos potenciales que pueden influir en sus resultados. Sin esta base conceptual, el riesgo es que la tecnología sea utilizada de manera superficial o acrítica, reproduciendo prácticas pedagógicas tradicionales bajo una apariencia de innovación.

Otro desafío relevante se relaciona con la transformación de las prácticas de evaluación. La disponibilidad de sistemas capaces de generar textos complejos, resolver problemas o producir código ha puesto en cuestión muchos de los métodos tradicionales de evaluación académica. En este contexto, el profesorado debe explorar estrategias evaluativas que prioricen el pensamiento crítico, la reflexión metacognitiva, la resolución de problemas complejos y la aplicación contextual del conocimiento. Más que prohibir el uso de la IA, la tarea consiste en diseñar experiencias de aprendizaje que integren estas herramientas de manera responsable, promoviendo la autoría intelectual y la integridad académica.

Asimismo, la IA plantea importantes desafíos éticos. La transparencia algorítmica, la protección de datos personales, la equidad en el acceso a la tecnología y la prevención del plagio asistido por IA son temas que requieren atención urgente en las instituciones de educación superior. El profesorado se encuentra en una posición estratégica para promover una cultura académica basada en el uso responsable de la tecnología, fomentando en el estudiantado una actitud crítica frente a las herramientas digitales y sus implicaciones sociales.

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En paralelo, la integración de la IA también exige repensar el desarrollo profesional docente. Las universidades deberán fortalecer programas de formación continua que permitan al profesorado actualizar sus competencias pedagógicas y digitales. Esto incluye no solo el aprendizaje técnico sobre nuevas herramientas, sino también la reflexión pedagógica sobre cómo estas tecnologías pueden contribuir a mejorar la calidad del aprendizaje y a responder a los desafíos de una educación superior cada vez más globalizada, interdisciplinaria y orientada a la innovación.

Desde una perspectiva más amplia, la IA invita a reconsiderar el papel del profesorado como mediador del conocimiento. En un entorno donde la información es abundante y fácilmente accesible, el valor del docente no reside únicamente en transmitir contenidos, sino en orientar procesos de aprendizaje significativos, promover el pensamiento crítico, estimular la creatividad y facilitar la construcción colectiva del conocimiento. La IA puede convertirse en un aliado en este proceso, siempre que su uso esté guiado por principios pedagógicos claros y por una visión humanista de la educación.

Finalmente, es importante reconocer que la transformación impulsada por la inteligencia artificial no es únicamente tecnológica, sino también cultural. La adopción de estas herramientas requiere cambios en las políticas institucionales, en los modelos de gobernanza universitaria y en las formas de concebir la innovación educativa. Las universidades que logren integrar la IA de manera estratégica y ética estarán mejor posicionadas para formar profesionales capaces de desenvolverse en sociedades cada vez más complejas y digitalizadas.

En este contexto, la discusión sobre el uso de la inteligencia artificial en la educación superior no debe centrarse exclusivamente en la tecnología, sino en el tipo de educación que deseamos construir para el futuro. El desafío para el profesorado consiste en aprovechar el potencial transformador de la IA sin perder de vista los principios fundamentales de la educación universitaria: el pensamiento crítico, la integridad académica, la formación integral y el compromiso con el desarrollo social. Solo así será posible avanzar hacia una educación superior que combine innovación tecnológica con responsabilidad ética y compromiso humanista.

Fernando Vera, PhD
Editor-in-Chief
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ORIGINAL ARTICLE

Development of an interdisciplinary educational resource to foster active and motivated learning

FRANCISCO JAVIER SAINZ MUÑOZ[1]
https://orcid.org/0009-0006-1013-248X
SALVADOR BAENA MORALES[2]
https://orcid.org/0000-0002-6722-3714
ALBERTO FERRIZ VALERO[3]
https://orcid.org/0000-0001-8206-4152

University of Alicante, Spain
Corresponding author: alberto.ferriz@ua.es

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Abstract
This article presents the design and implementation of *Kahbom*, a low-cost, game-based device intended to foster active and motivated learning. The study follows a descriptive qualitative design with 53 upper-secondary students (16–17 years old) from a public school in Spain. The device combines physical levers, light and sound feedback, and time-limited semantic challenges in which small groups must identify an impostor word to "defuse the bomb." Data were collected through an open-ended questionnaire and analysed using ATLAS.ti. Five main categories emerged from students' perceptions: positive acceptance, motivation, exploration, interest, and innovation. Results show high levels of enjoyment, cooperative engagement, and curiosity, as well as sustained attention during the activity. The discussion highlights the potential of hybrid ludic-technological resources for formative assessment, inclusive practice, and interdisciplinary learning, and outlines future lines of research to examine long-term motivational and learning effects.

Introduction

The importance of information and communication technologies (ICTs) in education is increasingly evident in the daily life of classrooms, both as a vehicle for learning and in specific subjects such as computer science or technology that are responsible for providing students with learning situations based on emerging digital tools (Balalle, 2024; Getenet et al., 2024). In Physical Education, however, teachers do not always know how to put ICTs at the service of education and make good use of them in the classroom, thereby failing to take full advantage of the benefits of these tools (Díaz Barahona, 2012). In addition, technological tools often do not introduce substantial innovations in Physical Education classes, even though teachers perceive that their implementation would be highly beneficial (Fernández-Espínola & Moreno, 2015).

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Game-based learning and gamification are resources that teachers are increasingly using, and this is also seen in the growing number of studies in recent years with this theme (Kim & Castelli, 2021; Li et al., 2023; Manzano-León et al., 2021). In addition, this gamification coupled with ICTs results in greater motivation in students and greater involvement in the proposed activities (Kim & Castelli, 2021; Li et al., 2023; Quintero González et al., 2018). Although physical education is a subject where the game is present in the classes, the same does not happen with ICT tools, since in physical education classes we find handicaps to make use of them, this is due to the use of outdoor tracks or pavilions, where there is not always internet connectivity and also in the yard we cannot connect to the electricity network, therefore, the use of ICTs in the subject is limited to ICT tools that do not depend on either internet connection or electricity connection for their use. In addition to these requirements, the tools must also be inclusive, so that students with disabilities can use them like any other student and not only as assistance tools (Fernández Batanero et al., 2021; Lynch et al., 2024; Samaniego López et al., 2025; Zárate-Rueda et al., 2025).

To introduce these tools, teachers have an ally, novelty. Some authors seek to adhere novelty as a basic psychological need, joining the already established Competence, Autonomy and Relatedness (González-Cutre et al., 2016). It has been shown that proposing novel methodologies and materials in physical education could cause an increase in students' intrinsic motivation (Fernández-Espínola et al., 2019). Teachers should be in constant search and learning about materials that students can visualize as novel and thus improve the learning experience of students, this work is not always well received by the teaching staff, where the older the age, the greater the disinterest and negative attitudes towards the use of ICT tools compared to younger groups of teachers (Díaz Barahona et al., 2018).

The satisfaction of basic psychological needs should be the focus of attention when planning, organizing and selecting educational experiences and materials in order to promote intrinsic motivation in the subject of physical education (Salazar-Ayala & Gastélum-Cuadras, 2020). This intrinsic motivation in students in the face of sports practice contributes to create an intentionality in the adolescent to be physically active in the future (Almagro Torres et al., 2011; García Soler, 2016).

Evaluation is a very important aspect of education—although not the only one—and it should not be used solely as an element of grading, but also endowed with a pedagogical purpose (Schunk & Zimmerman, 1998;Coll & Onrubia, 2002) so that the student can develop in all educational areas and thus see their basic psychological needs fulfilled at the time of evaluation being present. This evaluation process seeks to be formative and collaborative, where students are part of the evaluation process and can through evaluative practice produce improvements in student learning, providing them with autonomy and reflection in the process (Bizarro et al., 2019). One way to involve students in evaluation is to present them with evaluation tools that they can manipulate, use and learn about. ICTs, in addition to innovative elements, can provide evaluation situations that differ from what has been seen so far in a more traditional evaluation and can make the student more aware (Fernández-Espínola et al., 2019) of the evaluation process by having an instantaneous response giving rise to a reflection at the same time. The objective of this descriptive study is to present a proposal for educational material that is inclusive and facilitates a novel learning experience, as well as to offer suggestions for use and activities with this device as an axis in physical education classes for all educational stages.

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This work seeks to make a quality proposal where, from the teacher's point of view, students are more motivated to engage in sports practice through a material that promotes cooperation, teamwork and adapts to multiple gamifications to be carried out in the classroom. It also aims to be environmentally friendly, fulfilling the Sustainable Development Goal (SDG) number 12, corresponding to reduction and responsible consumption, of the 2030 agenda of sustainable development goals proposed by the United Nations (UN) among others such as SDG 4, quality education; SDG 5, gender equality and SDG 9, industry, innovation and infrastructure (UN, 2015).

In recent years the study of gamification in education has become increasingly relevant among researchers, defining the search with the terms gamification and education, for the last 5 full years and we find an upward trend in the number of publications collected by these search terms, which implies a greater interest in the scientific community for this area of knowledge in the world of education (Cavus et al., 2023; Li et al., 2023; Manzano-León et al., 2021).

Gamification is an active methodology that consists of introducing playful elements in the classroom by means of some innovative solution where students are actively involved in their learning. The subject of physical education is an environment in which games are present and it is easy to introduce them into the sessions. The aim of this teaching technique is that students perceive an improvement in the satisfaction of their basic psychological needs and an increase in intrinsic motivation while at the same time there is a decrease in demotivation (Ferriz-Valero et al., 2023; Mo et al., 2024; Sotos-Martínez et al., 2022). However, in the literature we also find studies reporting that, at the university level, intrinsic motivation is not modified by the use of gamification, but the grades obtained with respect to a control group are (Ferriz-Valero et al., 2020).

However, gamification not only increases student motivation and grades, but also requires cooperation between group members to achieve common goals. This supports the use of interactive groupings in the context of gamification, where students cooperate with each other for a common goal and dialogue is encouraged in physical education classes. This type of grouping also increases the degree of satisfaction of basic psychological needs, intrinsic motivation and level of theoretical knowledge (Cuartero et al., 2020; Ferriz-Valero et al., 2023). Additionally, it also brings benefits in disruptive situations that occur in the classroom by the students, as behavioural variables such as aggressiveness, irresponsibility, disobedience and disruption of classroom climate are significantly reduced (Ferriz Valero et al., 2019).

Currently, the UN has proposed an agenda for sustainable development, called Agenda 2030. In the creation of the device, some Sustainable Development Goals have been taken into account so that this innovative material complies with and brings this reality closer to the students. Specifically, the SDGs developed are SDG 4, quality education, since through this device the education that students will receive will be improved in vital aspects such as motivation or the satisfaction of basic psychological needs, among others; SDG 5, gender equality, thanks to the groupings and cooperative learning that the material promotes, gender equality will be promoted in physical education classes; (Bofill-Herrero et al., 2022) and SDG 9, industry, innovation and infrastructure; innovation of materials in the classroom helps in the classroom by working on novelty, which can be picked up as a basic psychological need. Moreover, in physical education, self-constructed material is used on numerous occasions and these practices related to SDG 12, sustainable consumption and production, are encouraged in physical education classes.

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Therefore, the teachers involved have a high awareness of sustainable development (Baena-Morales et al., 2021; Bofill-Herrero et al., 2022; Ruiz-Navas et al., 2024).

Methods and Materials

Study design

This study follows a descriptive qualitative design aimed at analysing students' perceptions of an educational game-based device (Kahbom) and examining its potential to enhance motivation, engagement, exploration, and active learning within Physical Education lessons. The intervention was implemented in real teaching conditions and integrated into regular class sessions, allowing the analysis to reflect authentic educational dynamics.

Participants

The sample consisted of 53 students enrolled in the first year of Upper Secondary Education (1st Baccalaureate) at a public high school in the province of Alicante (Spain). Two intact groups of the subject Physical Education participated, selected through convenience sampling according to their availability during the study period. Participants were approximately 16 to 17 years old and had previously completed compulsory Physical Education during lower secondary education, ensuring a relatively homogeneous level of experience in group dynamics and cooperative learning tasks. The intervention took place during regular school hours in the sports facilities of the centre, reproducing realistic classroom conditions.

Materials and device description

The central material of the intervention was a teacher-designed game-based device, hereafter referred to as Kahbom (Figure 1). The device consists of:

- A physical base equipped with four levers (representing "cables"),
- Velcro-attached words placed on each lever,
- A light and sound system that activates when the device "explodes".

Among the four words placed on the levers, three belong to the same semantic field, while one acts as the "impostor word". When the incorrect lever is activated, the device produces a symbolic "explosion" using lights and sound feedback. The system also includes a configurable time limit, after which the device activates automatically if the group has not completed the task. The device is portable, low-cost, and does not require an internet connection or external power source, making it suitable for outdoor or non-digital learning environments.

Figure 1. *Material used for the development of the activity*

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Procedure

Students were organised into four cooperative groups, each assigned one Kahbom device. The activity required them to identify the impostor word and deactivate the device correctly within a limited time. To achieve this, students searched the space for dispersed word cards, identified those belonging to the same semantic field, determined which word on the device did not appear in the collected set, and avoided activating the lever associated with the impostor word. Activating the correct three levers resulted in successful deactivation, whereas selecting the incorrect word triggered a light-and-sound "explosion".

The activity was designed to promote the active use of an innovative teacher-created device for formative assessment, encourage movement and physical activity through a search-based task, increase engagement and playful involvement, reinforce semantic-field learning across different curricular subjects, and foster cooperative work, shared decision-making, and peer communication. The task took place in the school gymnasium or sports court. Before the session, teachers prepared the devices and distributed ten word cards around the space (Figure 2). Each card derived from or related to the others, forming a coherent semantic network, while one of the words attached to each Kahbom device served as the distractor.

Figure 2. *Two examples of track leaves distributed by space (gym or track)*

Without receiving explicit instructions at the outset, students approached the challenge from a problem-solving perspective, collecting the distributed cards and recording them on a provided sheet (Figure 3). After identifying the complete semantic field, they returned to the device and selected the lever corresponding to the impostor word. A correct selection deactivated the Kahbom, whereas an incorrect one activated the symbolic explosion.

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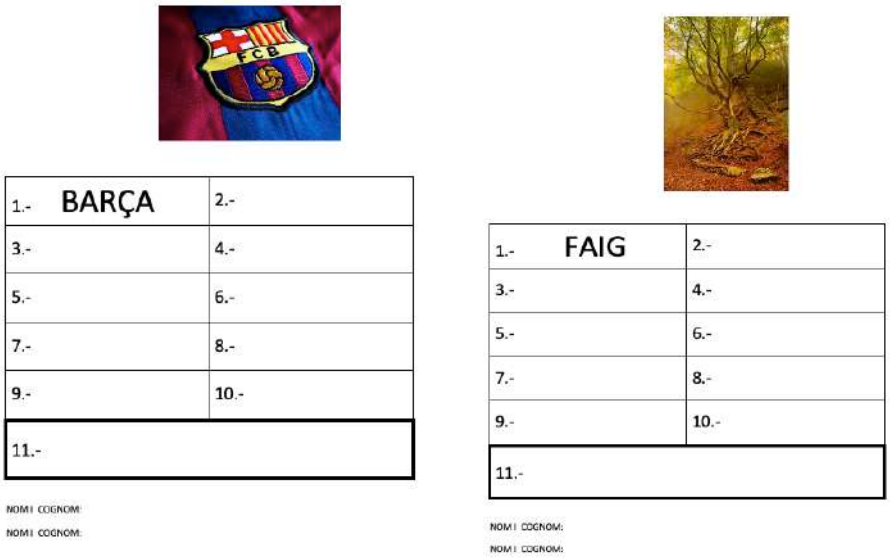
Figure 3. *Two examples of cards provided to students to complete the series of words*



This methodological proposal can be adapted to different educational levels by modifying the number of words and the complexity of the semantic categories. It is grounded in active learning, cooperative work, formative assessment, and problem-solving approaches. Teachers acted as facilitators throughout the process, activating the devices at the start of each round but refraining from intervening in students' decision-making. The spatial search component naturally integrated motor activity into the learning process, reinforcing the physical dimension of the task.

Evaluation instruments

To evaluate students' perceptions, an open-ended ad hoc questionnaire was administered on paper at the end of the third session. The questionnaire included five open items designed to explore:

- The perceived motivational value of the device,
- Its impact on learning and engagement,
- Elements of design that stimulated exploration or interest,
- Students' views on its potential applicability for future gamified activities.

No personal or sensitive data were collected. Each response sheet was assigned a numerical code to preserve anonymity. Paper questionnaires were later digitised for systematic analysis.

The tool was originally created with a specific use in mind, but during its development the broad potential of the device in education became evident, particularly its transversality, as it is applicable to all subjects and open to aesthetic modifications to adapt it to any educational context.

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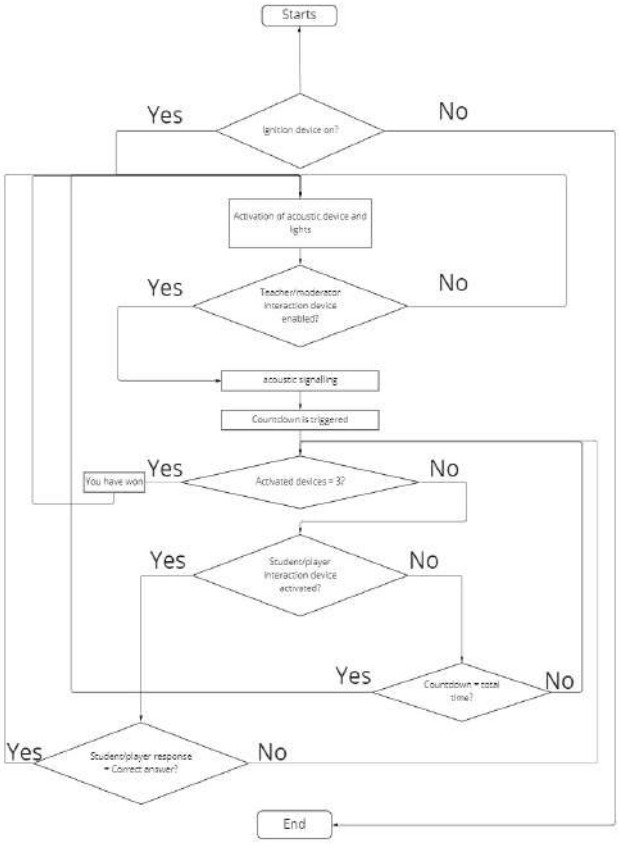
The main operation of the instrument is detailed below and a flowchart of the operation is shown in figure 4.

Figure 4. *Flow diagram of device operation*



Data Analysis

Data were uploaded to ATLAS.ti and analysed using a systematic qualitative coding protocol. Responses were segmented into units of meaning and categorised using a predefined coding tree structured into dimensions such as motivation, learning, and challenge. Associations between codes were examined through query tools, frequency counts, and co-occurrence analyses, allowing for the identification of recurrent patterns and emerging subthemes. This approach enabled a nuanced interpretation of students' experiences and perceptions.

Results

The qualitative analysis of student responses revealed five main categories, representing the most salient aspects of their experience with the Kahbom device: positive acceptance, motivation, exploration, interest, and innovation.

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These categories emerged from the frequency of citations in the coded dataset and reflect the students' perceptions of both the pedagogical value and the emotional impact of the activity. The distribution of categories is presented in Table 1.

Table 1. *Reference records in the category-ordered questionnaire replies*

Category	Frequency (n)	Percentage (%)
Positive acceptance	46	86.79%
Motivation	42	79.25%
Exploration	27	50.94%
Interest	26	49.06%
Innovation	23	43.40%

Positive Acceptance (46 references)

A total of 86.79% of the students positively evaluated the acceptance of the Kahbom device. Some of the highlighted statements included:

- "Yes, having to pull the levers and the lights really catch your attention, yes, because it has been entertaining to use something totally different from what we normally use."
- "I think what I liked the most could be the lights, but also the levers. Yes, because the fact of having to go and pull the levers and that it might explode makes it more competitive."
- "Yes, because it is very fun, and it is good for the groups to have more confidence and work more as a team, not individually."
- "The sound, since it is a sound that attracts me and works in an easy way. Because it is a game where you are active and also bond with people."
- "It is something new for us and very practical due to its wide variety of options, yes, because you can mix physical activity with general-knowledge questions."

In summary, a large proportion of students described the device as fun, engaging, and different from typical classroom materials. Many highlighted the lights, levers, and sound effects as elements that immediately captured their attention and fostered group cohesion. Remarks such as "the lights and levers make it much more exciting" or "it helps the group work as a team rather than individually" illustrate this strong positive reception.

Motivation (42 references)

A total of 79.25% of the students highlighted the motivational aspect of the activity, emphasising its capacity to generate positive tension and a spirit of healthy competition. Its similarity to a television game show and the challenge of "defusing the bomb" increased adrenaline and encouraged the group to stay involved until the very last second. Some participants expressed:

- "Yes, the fact that it has levers makes me feel like I am playing one of those games that appear on television."
- "The lights motivate quite a lot. If we had done the activity without the device, it would not have been as entertaining."
- "The similarity to the TV show Boom, because what draws our attention the most are the switches that looked like those on an airplane."

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- "Sharing different opinions with classmates to reach the solution, and the device made the activity more intense."

In sum, students frequently mentioned feeling highly motivated, emphasising the tension and excitement associated with the ticking timer and the challenge of preventing the "explosion." Several compared the device to television game shows, noting that these features increased adrenaline and sustained engagement throughout the task.

Exploration (27 references)

A total of 50.94% of the students highlighted the exploratory component of the activity, noting how the simple mechanism of switches sparked their curiosity and motivated them to try different strategies. The adaptability of the device allowed for the creation of varied narratives and tailored exercises, promoting collective solutions and the creative exchange of ideas. This spirit of experimentation strengthened group collaboration, as reflected in comments such as:

- "Yes, because it is something new for us and very practical due to its wide variety of options, because you can mix physical activity with general-knowledge questions."
- "The fact that it was entertaining to have to develop any technique to retrieve the puzzle."
- "Attractive and also different from what we usually do in class; it looked like a treasure, which awakened more curiosity."
- "It contributed to teamwork simply through the simple mechanism of switches."
- "In a way it grabs your attention, yes, like creating new activities, because with a simple bomb you can do many activities."

Overall, half of the participants valued the exploratory dimension of the activity. The simplicity of the mechanical system encouraged experimentation, creativity, and strategic thinking. Students reported that the device invited them to "try different techniques," "develop strategies," and "figure out the puzzle," reinforcing collaborative problem-solving.

Interest (26 references)

A total of 49.06% of the students highlighted the level of interest the game generated, emphasizing the curiosity to discover which lever had to be pulled next and the desire to get it right before it "exploded." This dynamic mechanic kept attention high throughout the entire session. As one student mentioned:

- "Yes, it is a way of doing several fun activities and learning by playing. Yes, I find it interesting how the device knows which lever to pull so that it does not explode as the objectives change."
- "The fact that it has buttons to pull and that it might explode if you make a mistake, I think that makes it more interesting."
- "It made it a very dynamic game, because without the tension of defusing the bomb, it would not be the same."
- "Yes, because having the device and being able to pull the levers increases the interest in finding the correct answer."
- "Yes, because it increases the interest and the desire to carry out the activity."

To summarize, nearly half of the responses highlighted that the constant decision-making process—combined with the risk of triggering the explosion—maintained their interest and focus. Comments referred to the activity as "dynamic," "attention-grabbing," and "stimulating," with the device serving as a central element in maintaining engagement.

Innovation (23 references)

A total of 43.40% of the students highlighted the innovation of the device, valuing especially its novel combination of technology and play in the Physical Education environment. This element of originality not only broke traditional patterns but also encouraged collective creativity when proposing alternative dynamics. Several participants stated:

- "The joystick, you can choose the answer; yes, because it is something innovative in class, that it lights up and makes noise when you make a mistake."
- "The novelty, because it was a new object; yes, because you had the tension of whether the option would be the correct one or not."
- "Yes, because with it the situation is more realistic; I can make the activity more entertaining due to its originality and realism."
- "Yes, since I would have liked to see how it works and see all the work behind it. Of course, it is something innovative that people do not know they can learn with, and it is very motivating."
- "Because it is innovative and we are not used to this type of game; it attracts the attention of the class and you compete to complete the game correctly in the shortest possible time."

In essence, students recognised the device as innovative, noting the novelty of integrating physical mechanisms with playful dynamics in Physical Education. The originality of the tool sparked curiosity about its internal functioning and encouraged discussion about how it could be used in other subjects.

Discussion

The results of this study demonstrate that the Kahbom device generated a substantial pedagogical impact on student motivation, engagement and participation in Physical Education settings. The notably high level of positive acceptance (86.79%) indicates that multisensory and game-based stimuli function as effective mediators for initiating group involvement, lowering the entry barrier to participation and establishing a supportive social climate. This finding is consistent with Self-Determination Theory, which posits that the fulfilment of basic psychological needs fosters intrinsic motivation and long-term engagement (Almagro Torres et al., 2011; Manzano-León et al., 2021; Salazar-Ayala & Gastélum-Cuadras, 2020). In particular, the device's novelty—the combination of physical manipulation, sound effects and time pressure—appears to satisfy the need for novelty proposed by González-Cutre et al. (2016), reinforcing the idea that innovative materials can stimulate students' interest and willingness to participate (Ferriz-Valero et al., 2023).

Motivation emerged as a central dimension, with 79.25% of students describing heightened activation, emotional tension and sustained engagement. The resemblance of the activity to a television game show—a familiar and culturally recognised format—may have contributed to increasing students' enjoyment and sense of challenge, an effect previously reported in studies on gamification in Physical Education (Ferriz-Valero et al., 2023; Kim & Castelli, 2021; Li et al., 2023; Quintero González et al., 2018; Sotos-Martínez et al., 2022). The combination of countdown, uncertainty and collective decision-making appears to have triggered a playful competitive environment that promoted meaningful group interaction.

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This aligns with findings indicating that gamified challenges can enhance both motivational processes and social competencies in school-age learners (Ferriz Valero et al., 2019; Mo et al., 2024).

The exploratory nature of the activity—highlighted by 50.94% of participants—supports the idea that educational technologies can serve as "creative platforms" enabling experimentation, strategy development and adaptive task design. Students used the device to engage in problem-solving processes, draw semantic connections and construct collaborative narratives, aligning with pedagogical models based on active learning and project-based methodologies (Cavus et al., 2023; Manzano-León et al., 2021). This result is consistent with Cuartero et al. (2020), who emphasise that interactive group tasks enhance cooperative dialogue, shared responsibilities and collective reasoning within Physical Education.

Sustained interest (49.06%) further demonstrates that the dynamic nature of the task—particularly the sequential manipulation of levers and the anticipation of the "explosion"—maintains attention and reduces disengagement, a recurrent challenge in practical subjects. The combination of time constraints, embodied action and immediate feedback may have facilitated states of focused involvement similar to flow, reinforcing the relationship between challenge, perceived competence and enjoyment (García Soler, 2016; Fernández-Espínola et al., 2019). These findings suggest that well-designed ludic mechanisms can be harnessed to improve attentional regulation in environments characterised by movement and spatial dispersion (Fernández-Espínola et al., 2019; García Soler, 2016; Mo et al., 2024).

Innovation (43.40%) was also frequently mentioned, indicating that Kahbom was perceived as a disruptive and original component within a subject where technological integration remains limited (Balalle, 2024; Díaz Barahona, 2012; Fernández-Espínola & Moreno, 2015; Karabin et al., 2024). The hybrid nature of the device—combining tactile mechanics with game-based dynamics—aligns with recent calls for sustainable, low-cost and scalable educational innovations capable of overcoming infrastructural barriers in Physical Education (Baena-Morales et al., 2021; Bofill-Herrero et al., 2022; Lynch et al., 2024). Moreover, the device's modularity and adaptability open possibilities for interdisciplinary use, reinforcing its potential to support learning across curricular areas.

The activity also revealed implications for formative assessment. The problem-solving structure of the task required students to articulate decisions, justify their reasoning and collaborate under pressure—elements aligned with contemporary perspectives on formative assessment that emphasise autonomy, reflection and shared evaluation processes (Bizarro et al., 2019; Cavus et al., 2023; Coll & Onrubia, 2002). The device offers an accessible means of transforming assessment into an interactive and participatory experience, reducing its association with purely summative or individual forms of measurement.

Nonetheless, these findings must be interpreted considering several limitations. The study was conducted with a relatively small and homogeneous sample from a single institution, limiting external validity. The short duration of the intervention does not allow us to determine whether the high levels of motivation and interest reflect sustained engagement or a novelty effect. Moreover, the activity was implemented in Physical Education only; its interdisciplinary potential remains theoretical and requires empirical validation. Future studies should incorporate longitudinal designs, comparison groups and objective indicators of learning and performance to better understand the long-term impact of the device.

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Overall, the results provide strong support for the pedagogical viability of hybrid ludic-technological tools in Physical Education. The convergence of positive acceptance, motivation, exploration, interest and innovation establishes a solid foundation for integrating such devices into active and collaborative methodological frameworks.

Conclusions

The present study demonstrates that Kahbom is a highly promising pedagogical resource capable of transforming learning dynamics in Physical Education through game-based mechanisms, multisensory cues and collaborative problem-solving. The consistently high levels of positive acceptance and motivation observed suggest that the device effectively satisfies key psychological needs identified by Self-Determination Theory—particularly competence and novelty—while simultaneously fostering group cohesion and enjoyable engagement. These features position Kahbom as more than a motivational add-on: it operates as a structural enhancer of active learning environments.

The strong exploratory and interest dimensions reflect the device's versatility and creative potential. Its modular structure, adaptability to multiple narratives and capacity to integrate cognitive and motor tasks make it a powerful tool for interdisciplinary applications. Beyond its immediate use in Physical Education, the device holds potential for language learning, mathematics, science and humanities, where semantic reasoning, problem-solving and cooperative inquiry can benefit from ludic frameworks.

From an organisational perspective, Kahbom represents a scalable and cost-efficient innovation. Its ease of construction and maintenance allows for implementation in schools with limited resources, and its simplicity enables students themselves to participate in its assembly and improvement. This aligns with calls for sustainable and inclusive educational innovation, reflecting broader goals outlined in the Sustainable Development Goals—particularly SDG 4 (Quality Education), SDG 9 (Industry, Innovation and Infrastructure) and SDG 12 (Responsible Consumption).

For sustained adoption, teacher training will be essential. Professional development programmes focusing on challenge-based instruction, formative assessment and inclusive pedagogies would allow educators to maximise the device's pedagogical potential. Establishing communities of practice could further support the sharing of scenarios, adaptations and evidence-based reflections.

While this study offers encouraging insights, further empirical research is needed. Longitudinal analyses should examine whether the motivational effects endure over time and whether Kahbom influences learning outcomes, physical engagement or socio-emotional development. Evaluating its impact in other curricular areas will also be necessary to fully validate its interdisciplinary value.

In sum, Kahbom represents an accessible and innovative contribution to the growing field of playful learning technologies. By merging low-cost engineering with evidence-based pedagogical principles, the device positions play as a central resource for active learning, instructional innovation and the creation of inclusive, participatory classroom communities.

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ORIGINAL ARTICLE

Ethical opportunities and challenges of AI in mental health in Latin America

JUAN P. LÓPEZ[1]
https://orcid.org/0009-0007-2091-4482
FERNANDO VERA[2]
https://orcid.org/0000-0002-4326-1660
TOBÍAS A. PARODI[3]
https://orcid.org/0000-0003-4548-1058

[1]National Unified Corporation for Higher Education (CUN), Colombia
[2]University of th Basque Country, Spain
[3]University of Cordoba, Colombia

Corresponding author: juan.lopez@cun.edu.co

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Abstract

Artificial intelligence (AI) has emerged as a promising alternative to address the mental health crisis in Latin America and the Caribbean, characterized by a high prevalence of disorders, a shortage of professionals, and profound structural inequalities. This study aims to critically analyze the opportunities, applications, and ethical challenges of AI in mental health within the regional context. Using a critical and integrative narrative review, academic literature and normative documents published between 2020 and 2025 are examined, including empirical studies, reviews, and regulatory frameworks relevant to the region. The results reveal an emerging landscape in predictive diagnosis, emotional monitoring, and chatbots, yet limited by algorithmic biases, the lack of representative data, and the absence of specific regulations. It is concluded that the effective implementation of AI in mental health requires a responsible development approach that articulates ethical governance, strengthening of local capacities, and sociocultural adaptation, prioritizing equity and protection of vulnerable populations.

Introduction

Over the past decade, artificial intelligence (AI) has become established as a major driver of transformation across multiple sectors, including mental health. In the Latin American context, this technology has gained relevance in response to persistent challenges such as a shortage of professionals, limited access to quality services, high demand and territorial inequalities, all of which are intensified by stigma, low levels of public investment, and the lack of preventive strategies.

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AI offers alternatives to reduce these gaps through tools such as therapeutic chatbots, predictive models, and generative systems, which can optimize care delivery, reduce costs, and provide continuous support. Recent studies show that machine learning and natural language processing facilitate early detection and management of symptoms associated with anxiety, depression, and other prevalent disorders.

However, implementation in the region remains incipient. Limitations persist in regulatory frameworks, the availability of representative data, and cultural acceptance. A central challenge is algorithmic bias derived from the use of data from high-income countries, which affects the validity and equity of solutions in Latin American contexts. This chapter presents a narrative review of the current state of AI in mental health, with particular attention to its applicability, ethical challenges, and development opportunities in Latin America.

Methods and Materials

This study is based on a critical and integrative narrative review aimed at synthesizing available knowledge on the use of artificial intelligence (AI) applied to mental health in Latin America and the Caribbean (LAC). Unlike a systematic review, whose primary objective is exhaustiveness, this approach seeks to interpret trends, contrast perspectives, and analyze regional implications based on diverse and recent evidence. This methodological choice responds to the emerging nature of the topic and the heterogeneity of studies available in the region.

Sources consulted: Academic literature published between 2020 and 2025 was reviewed, including empirical studies, systematic reviews, scoping reviews, and meta-analyses indexed in PubMed, Scopus, SciELO, and Google Scholar. In addition, public policy documents, science and technology agendas, guidelines from multilateral organizations, and analyses of regulatory frameworks related to health and AI were included. The incorporation of grey literature reflects the fact that much regulation, governance, and pilot experience has not yet been reported in indexed journals.

Selection criteria: Priority was given to publications meeting at least one of the following criteria: (a) studies conducted in LAC countries or with results applicable to the region; (b) research on AI applications in mental health; (c) normative or technological governance documents; and (d) evidence on inequality, access, or social impact related to digital health technologies.

Synthesis and organization. The evidence was analyzed thematically and structured into five dimensions: regional context; technological landscape; structural inequalities, barriers, and ethical challenges; regulatory situation; and proposals for responsible development.

This methodological approach makes it possible to understand the current state of the field, identify critical gaps, and propose development opportunities aligned with the sociotechnical realities of LAC. For this purpose, it is first necessary to situate the current state of mental health and its determinants in Latin America and the Caribbean.

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Results

The results of this review reveal an emerging landscape of AI applications in mental health across LAC. Analysis of the literature shows advances in the adoption of predictive models, natural language processing tools, and therapeutic chatbots, mainly oriented toward diagnosis, prevention, and emotional support. The evidence makes it possible to identify prevailing technological trends, the most frequently studied disorders, and persistent methodological gaps.

Mental health context in Latin America

Mental health in Latin America and the Caribbean (LAC) is characterized by a high prevalence of disorders, limited institutional capacity, and deficiencies in the quality of epidemiological data. A recent review identified 69 national surveys conducted over the past decade, with an emphasis on substance use and violence, while depression, anxiety, suicidal behavior, and dementias remain underrepresented (Ramírez-Bontá et al., 2023). In addition, the concentration of instruments in Mexico and Colombia hinders a balanced regional perspective.

These limitations also affect research in artificial intelligence (AI). Tornero-Costa et al. (2023) point to recurrent methodological shortcomings such as small sample sizes, limited external validation, and data not originally designed for AI applications, which restrict the development of culturally relevant models and perpetuate existing gaps. The COVID-19 pandemic further intensified these weaknesses; a meta-analysis reported pooled prevalences of 35% for anxiety, depression, and insomnia, higher than those observed in Asia and Europe (Zhang et al., 2022), with a particularly strong impact in South America.

Taken together, the evidence points to high mental health needs combined with insufficient capacity, shaping public policy design and conditioning the ethical and effective adoption of emerging technologies such as AI, whose success depends on reliable and context-specific information.

Current landscape of AI applied to mental health: Recent initiatives in Latin America and the Caribbean

In recent years, Latin America has increased its scientific output in AI and mental health, mainly concentrated in Colombia, Mexico, and Chile. Applications based on machine learning (ML), natural language processing (NLP), and therapeutic chatbots predominate, focusing on depression, anxiety, stress, bipolar disorder, and behavioral difficulties.

Table 1 summarizes the most relevant initiatives identified in the region. In Colombia, Santamaría-García et al. (2023) applied ML to analyze healthy aging; in Chile, Gaona et al. (2025) used Random Forest algorithms for bipolar disorder; and Daza et al. (2023) documented rapid growth in ML applications across the region. In parallel, NLP-based chatbots show promising results: Entenberg et al. (2023) reported good acceptability among young people with behavioral problems, while Terán et al. (2024) highlighted their potential to expand access in public health contexts.

Despite these advances, the field remains fragmented and methodologically weak, with predominantly descriptive studies, small samples, and limited external validation. Nevertheless, these initiatives reflect growing interest and openness to AI-based solutions adapted to the Latin American context as a complement to traditional clinical practice.

Table 1. *Initiatives in Latin America and the Caribbean*

Author(s) / Year	Country(ies)	AI Technology / Approach	Disorders or problems addressed	Main findings
Santamaría-García et al. (2023)	Colombia	Machine Learning (ML) / predictive models	Psychosocial factors related to healthy aging	Identified relevant patterns using ML to characterize well-being and mental health in older adults; highlighted predictive utility with limitations in generalizability.
Daza et al. (2023)	Multi-country (LAC)	Systematic review of ML in mental health	Depression, anxiety, stress	Documented rapid growth in ML use across the region, alongside methodological shortcomings such as small samples and lack of external validation.
Entenberg et al. (2023)	Uruguay / Chile	NLP-based chatbot	Behavioral problems in youth	The microintervention chatbot showed good user acceptability; preliminary results suggest utility for behavioral support.
Terán et al. (2024)	Ecuador	Narrative review on chatbots and public health	Stress, general emotional distress	Analyzed the potential of chatbots to expand access to services; highlighted adoption challenges and sociocultural barriers in LAC.
Gaona et al. (2025)	Chile	Random Forest (RF)	Bipolar disorder	RF models identified relevant patterns that could support diagnosis and monitoring; emphasized the need for larger samples and clinical validation.

Source: Authors' own elaboration.

Technological applications

Significant advances are observed in the region with the use of predictive models, particularly for diagnosis and risk prediction of disorders such as anxiety and depression, using machine learning (ML) and natural language processing (NLP) algorithms. In addition, therapeutic chatbots such as Woebot and Wysa, based on cognitive-behavioral therapy (CBT), are being used successfully to provide emotional support and monitor patients in resource-constrained settings. Table 2 presents additional examples.

Table 2. *Examples of AI technologies applied to mental health*

Technology	Main applications	Disorders addressed
Machine Learning (ML)	Clinical prediction, risk classification	Anxiety, depression, suicide risk
Natural Language Processing (NLP)	Therapeutic chatbots, emotion analysis	Anxiety, depression
Deep Neural Networks (DL)	Voice analysis, neuroimaging	Schizophrenia, bipolar disorder

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Technology	Main applications	Disorders addressed
Generative AI	Development of intervention plans, psychoeducational materials	Depression, bipolar disorder

Source: Authors' own elaboration.

However, the expansion of these applications raises important ethical and social questions, especially in a region marked by deep inequalities. The following section analyzes barriers, risks, and ethical challenges associated with the use of AI in mental health in LAC.

Barriers, ethical, social, and structural challenges: Adoption of AI in mental health in Latin America

The adoption of artificial intelligence (AI) in mental health in Latin America and the Caribbean (LAC) is shaped by a set of interrelated barriers reflecting historical structural inequalities, institutional limitations, and ethical challenges. Social factors such as poverty, stigma, and unequal access to health services combined with gaps in digital infrastructure, professional capacity, and the production of high-quality data, directly affecting the feasibility and equity of AI-based solutions.

These conditions have a particularly strong impact on vulnerable populations. A recent study on adolescents exposed to social inequality in the region shows that structural factors such as violence, food insecurity, and discrimination operate as chronic stressors associated with increased risk of depression and anxiety (Sánchez-Castro et al., 2024). This illustrates how socioeconomic disparities affect not only disorder prevalence but also the ability to benefit from digital tools amid connectivity and digital literacy gaps.

At the same time, ethical and social challenges persist regarding the use of sensitive data, potential cultural and linguistic biases, algorithmic transparency, and protection of user autonomy. Systems trained on non-representative data may generate inaccurate decisions or perpetuate inequities. Institutionally, scientific agendas often marginalize mental health and lack clear strategies for the development or regulation of AI (Ragusa et al., 2025).

Recommendations to address ethical and social challenges

The literature proposes concrete measures to strengthen the ethical use of artificial intelligence (AI) in mental health in Latin America and the Caribbean (LAC):

- Develop clear and specific regulatory frameworks, with standards for the management of sensitive data, algorithmic audits, and mandatory human oversight (Rubeis, 2022; Fanarioti & Karpouzis, 2025).
- Foster transparency and applicability by adopting documentation practices, technical reporting, and mechanisms that enable understanding of the underlying logic of AI models (Saeidnia et al., 2024; Olawade et al., 2024).
- Promote representative datasets, built with the participation of local communities and cultural diversity, to reduce bias and improve clinical accuracy (Mancilla-Caceres & Estrada-Villalta, 2022).
- Advance digital literacy strategies, targeting both professionals and patients, to ensure informed and responsible use of these technologies (Ruano et al., 2021).

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- Ensure community participation, including users, families, and professionals, in the design and evaluation of technological tools in order to guarantee cultural relevance and social legitimacy (Mancilla-Caceres & Estrada-Villalta, 2022).

While these recommendations provide practical guidance for a more ethical and socially responsible use of AI, their implementation requires regulatory frameworks that support their operationalization. Therefore, it is necessary to examine the current regulatory landscape and normative needs in the region.

Regulatory situation and normative needs

Regulation of artificial intelligence (AI) applied to health in Latin America and the Caribbean (LAC) remains at an early stage, with uneven progress across countries. Existing frameworks mainly focus on data protection, digital ethics, and general transparency. However, specific regulation for AI in mental health is scarce and usually subsumed under broader digital health guidelines, limiting oversight of technologies that handle highly sensitive information.

Regulatory development is heterogeneous. Brazil has implemented the General Data Protection Law (LGPD), which recognizes the right to explanation and review of automated decisions automatizadas (De Araujo Dourado & Aith, 2022). Peru is the only country with a specific regulation for AI in medicine, although its implementation is still being consolidated (Zavaleta-Monestel et al., 2025). In Argentina, Mexico, Colombia, and Chile, proposals focus primarily on privacy and risk management (Ragusa et al., 2025). Significant gaps remain in legal responsibility, institutional oversight, and protection against bias, particularly for vulnerable populations.

The literature highlights the need for specific frameworks for AI in mental health due to risks of bias, discrimination, or manipulation (Fanarioti & Karpouzis, 2025). In LAC, there are no regulations exclusively targeting this area, nor minimum standards for clinical validation or crisis protocols. The EU Artificial Intelligence Act (Regulation (EU) 2024/1689), which classifies mental health tools as high-risk, is frequently cited as a global reference underscoring the need for more specific frameworks in LAC (Eraso, 2024).

Based on the regional and comparative analysis, several urgent regulatory needs can be identified in Latin America and the Caribbean (LAC):

1. Specific regulations for AI in mental health, establishing minimum requirements for safety, clinical validation, and oversight.
2. Regional standardization of ethical and technical criteria, particularly for the management of sensitive data and vulnerable populations.
3. Legal accountability mechanisms for automated decisions affecting diagnoses, prognoses, or interventions.
4. Algorithmic validation and auditing protocols, including assessments of linguistic, cultural, and socioeconomic bias.
5. Clear definitions of the role of human oversight, especially in emotional support tools or chatbot-based interventions.
6. Regulation of generative models applied to psychological interaction, which is currently absent in the LAC region.

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These needs constitute a natural bridge to the following section, which focuses on proposals and lines of action for responsible development.

Proposals for the responsible development of AI in mental health in Latin America and the Caribbean

Responsible development of AI applied to mental health requires the integration of ethical principles, technical standards, specific regulations, adequate infrastructure, and community participation. The literature emphasizes the adoption of international governance frameworks, strengthening of local capacities, and regional and interdisciplinary collaboration to ensure safe, equitable, and effective solutions in LAC.

Ethical governance and international frameworks

Core principles include privacy, equity, bias mitigation, transparency, explainability, informed consent, and accountability (Saeidnia et al., 2024; Fanarioti & Karpouzis, 2025; Olawade et al., 2024; Rubeis, 2022; Wang et al., 2024). International organizations emphasize regulatory frameworks and continuous risk assessment (Shaw et al., 2024), while ISO, IEC, and IEEE promote technical standards for quality and transparency (Goktas & Grzybowski, 2025). The EU AI Act serves as a reference for guiding frameworks in LAC given the high-risk nature of these applications (Eraso, 2024).

Technical standards and scientific validation

Clinical reliability depends on adherence to standards such as TRIPOD-AI, CONSORT-AI, and STARD-AI. TRIPOD-AI provides criteria for predictive models (Collins et al., 2021; Collins et al., 2024); CONSORT-AI extends reporting guidelines for trials involving AI (Liu et al., 2020; Ibrahim et al., 2021); and STARD-AI adapts diagnostic accuracy guidelines to predictive technologies (Sounderajah et al., 2021). Adherence rates remain around 50%, highlighting the need for greater methodological rigor (Kleine et al., 2024; Martindale et al., 2024; Wilhelm et al., 2024; Koutsouleris et al., 2022).

Infrastructure, technical capacity, and specialized training

AI adoption requires investment in secure and interoperable platforms. Frameworks such as GDPR, HL7 FHIR, and ISO/IEC 27001 are key references for security and traceability (Pesqueira et al., 2025; Löchner et al., 2025). The development of academic and clinical hubs capable of certifying tools prior to implementation is recommended, along with scalable infrastructures for federated learning, private clouds, and ethical use of generative models (Ng et al., 2025; Naik, 2023; Strudwick et al., 2025). Integrating data science and AI into the training of psychologists and psychiatrists is a key enabler for informed adoption (Jazayeri et al., 2025).

Cultural adaptation of technology

Implementing AI in mental health in Latin America requires trained models on representative data of local realities. Cultural, linguistic, and social differences influence how digital interventions are perceived (Katsina, 2024; Kasaudhan, 2025). Ensuring cultural relevance improves accuracy, therapeutic utility, and acceptance, particularly in contexts where stigma persists (Vielma-Aguilera & Castro-Alzate, 2021).

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Interdisciplinary collaboration

Responsible adoption requires coordination between engineering, mental health, and ethics to ensure technically robust solutions that respect privacy and align with clinical practice principles, especially when managing sensitive data (Spytska, 2025). This collaboration helps ensure that digital tools complement rather than replace human interaction (Cecil et al., 2025).

Community participation, equity, regional research, and international cooperation

The involvement of users, families, and professionals strengthens cultural relevance and social acceptance of AI (Paz et al., 2025). Epistemic justice promotes local agency, although funding limitations persist. Regional research networks and international organizations, such as RedeAmericas, HEROES and LAC-CD, support collaborative initiatives aimed at ethical, equitable, and sustainable AI development (Ragusa et al., 2025; Paz et al., 2025).

Conclusions

Artificial intelligence (AI) offers significant opportunities to improve mental health care in Latin America and the Caribbean, particularly in predictive diagnosis, continuous monitoring, and expanded access in contexts with professional shortages. Its implementation could help reduce longstanding barriers and support more timely, personalized, and sustainable care strategies.

Nevertheless, limitations related to data availability and quality, research fragmentation, and the still incipient validation of models designed for the regional context persist. Ethical challenges associated with bias, transparency, and privacy are amplified in a setting marked by social inequalities and digital divides, requiring caution and responsible design.

The absence of coherent regulatory frameworks represents both a challenge for oversight and user protection and an opportunity to design norms tailored to regional realities. Advancing toward AI applied to mental health that is effective, equitable, and culturally relevant requires strengthening local research capacities, fostering interdisciplinary collaboration, and consolidating regional agreements that ensure minimum standards of safety, transparency, and quality.

Ultimately, the promise of AI in mental health will depend less on technology adoption itself and more on the collective construction of a responsible innovation ecosystem. Integrating ethical principles, local knowledge, and community participation can transform these tools into meaningful support for guaranteeing the right to mental health and expanding opportunities for well-being across the region.

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Declaration of interests

The authors declare that there are no conflicts of interest related to this research.

Author contributions

During the preparation of this work, DeepSeek was used as an assistance tool to improve readability, synthesize information, and preliminarily structure the content, and ChatGPT was used to refine the translation. Following the use of these tools/technologies, the authors assumed full responsibility for reviewing and editing the content in its entirety, ensuring the accuracy and integrity of the published information and taking full intellectual responsibility for the final manuscript.

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ARTÍCULO ORIGINAL

Inteligencia artificial como herramienta de apoyo terapéutico en salud mental: Perspectiva América Latina. Revisión sistemática

JUAN P. LÓPEZ[1]
https://orcid.org/0009-0007-2091-4482
[1]Corporación Unificada Nacional de Educación Superior (CUN), Colombia

Autor de correspondencia: juan.lopez@cun.edu.co

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Resumen

La presente investigación realiza una revisión sistemática sobre el uso de la Inteligencia Artificial (IA) en el tratamiento de la salud mental, con énfasis en América Latina. Se analizan los métodos y modelos de IA más utilizados, como el procesamiento de lenguaje natural, el aprendizaje automático y las redes neuronales profundas, empleados en la detección, monitoreo y apoyo terapéutico de trastornos como ansiedad, depresión y esquizofrenia. Además, se examinan las principales arquitecturas tecnológicas, los desafíos éticos y la ausencia de marcos regulatorios regionales. Los resultados pretenden identificar oportunidades de desarrollo tecnológico aplicable desde la ingeniería de sistemas, orientadas a mejorar la accesibilidad, la eficacia y la equidad en la atención en salud mental. Se concluye la necesidad de impulsar investigaciones interdisciplinarias y marcos normativos que promuevan una integración responsable de la IA en este campo.

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Artificial intelligence as a therapeutic support tool in mental health: Latin American oerspective. Systematic review

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Abstract

This study presents a systematic review on the use of Artificial Intelligence (AI) in mental health treatment, with emphasis on Latin America. The most frequently applied AI methods and models are analyzed, including natural language processing, machine learning, and deep neural networks, used for detection, monitoring, and therapeutic support of disorders such as anxiety, depression, and schizophrenia. In addition, the main technological architectures, ethical challenges, and the absence of regional regulatory frameworks are examined. The findings aim to identify technological development opportunities applicable from systems engineering, oriented toward improving accessibility, effectiveness, and equity in mental health care. The study concludes with the need to foster interdisciplinary research and regulatory frameworks that promote the responsible integration of AI in this field.

Introducción

La salud mental se ha consolidado como una prioridad crítica de salud pública a nivel global, con una resonancia particularmente aguda en América Latina. En esta región, persisten brechas estructurales profundas en el acceso, la cobertura y la calidad de la atención. Factores como la insuficiencia de profesionales especializados, con ratios que en Colombia descienden a 2,5 psiquiatras por cada 100.000 habitantes, muy por debajo de los estándares internacionales y una baja inversión pública en servicios de salud mental, que ronda solo el 2% del gasto total en salud (IntraMed, 2025), y un estigma social persistente, convergen para crear una barrera que impide a una gran proporción de la población recibir una atención adecuada y oportuna. La pandemia de COVID-19 no hizo más que exacerbar esta crisis silenciosa, incrementando de forma preocupante la prevalencia de trastornos como la ansiedad y la depresión (Programa de las Naciones Unidas para el Desarrollo [PNUD], 2025).

El impacto de este déficit trasciende lo puramente clínico, extendiéndose a lo económico y social. Informes recientes de la Organización Panamericana de la Salud (OPS, 2025) estiman que Sudamérica enfrentará pérdidas económicas superiores a los 7 billones de dólares entre 2020 y 2050 debido a las enfermedades no transmisibles y los trastornos de salud mental. En un contraste revelador, invertir en tratamientos para trastornos mentales comunes ofrece un retorno económico cuatro veces superior (Chisholm et al. (2016); El País, 2025). Este escenario plantea un desafío monumental para los sistemas de salud de la región, obligándolos a buscar soluciones innovadoras y escalables para cubrir una demanda creciente (Gutiérrez *et al.,* 2024).

Paralelamente, el desarrollo acelerado de la Inteligencia Artificial (IA) ha irrumpido en el ámbito de la salud, abriendo nuevas y prometedoras oportunidades (Alowais *et al*., 2023). En el campo de la salud mental, la IA se ha implementado en herramientas como chatbots conversacionales, sistemas predictivos y modelos de aprendizaje profundo, mostrando resultados alentadores en el acompañamiento

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terapéutico y la detección temprana (Cruz-González et al., 2025; Spytska, 2025). Tecnologías como el Procesamiento de Lenguaje Natural (PLN) permiten analizar emociones a partir de texto y voz; el Aprendizaje Automático (ML, por sus siglas en inglés) identifica patrones complejos para predecir riesgos de depresión o ansiedad; y las Redes Neuronales Profundas (DL) se aplican al análisis de neuroimágenes o datos multimodales para trastornos más complejos (Zhang & Wang, 2024).

Sin embargo, existe una desconexión crítica entre el avance global y la realidad regional. Aunque herramientas como Woebot o Wysa han demostrado eficacia en contextos controlados (Inkster et al., 2018; Prochaska *et al*., 2021), la evidencia sobre su aplicabilidad, validez y sostenibilidad en América Latina es escasa. La mayoría de los desarrollos y validaciones se han realizado en poblaciones de países de altos ingresos, lo que plantea serios desafíos de sesgo algorítmico, pertinencia cultural y falta de generalización (Torous & Blease, 2024; Vera & Rodríguez-Flórez, 2025). Esta problemática justifica la necesidad de investigaciones que analicen el estado actual y las oportunidades de la IA en este contexto específico.

Por lo tanto, este trabajo se orienta a indagar cuál es el estado de uso de la IA como herramienta de apoyo terapéutico en América Latina, y qué oportunidades tecnológicas existen para su desarrollo desde la ingeniería de sistemas. El objetivo de esta investigación es analizar las herramientas, modelos y métodos de Inteligencia Artificial más utilizados en el tratamiento de la salud mental, con énfasis en su aplicabilidad, desarrollo y oportunidades de mejora en América Latina. Para ello, se plantean los siguientes objetivos específicos:

- Identificar los métodos y algoritmos de IA más utilizados en intervenciones terapéuticas
- Comparar las arquitecturas y entornos de desarrollo más comunes en estas soluciones
- Proponer líneas de desarrollo e investigación acordes con la revisión de la literatura y el contexto regional.

Método

La presente investigación adoptó un enfoque metodológico de revisión sistemática, siguiendo los lineamientos PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) para garantizar la exhaustividad y transparencia del proceso (Page *et al*., 2021). El diseño fue cuantitativo-descriptivo, con un alcance exploratorio que permitió mapear el estado del arte e identificar patrones en el uso de la Inteligencia Artificial (IA) en salud mental dentro del contexto latinoamericano.

La población de estudio estuvo constituida por la literatura científica publicada entre enero de 2020 y mayo de 2025. La búsqueda se realizó en cinco bases de datos académicas: Google Scholar, IEEE Xplore, PubMed, Scopus y Scielo, utilizando una estrategia de búsqueda específica para cada una de ellas siguiendo términos controlados (MeSH, TITLE-ABS-KEY, etc.), ejemplo representativo con Scopus en la Tabla 1. Este proceso de identificación arrojó un total de 1.076 registros iniciales.

Los criterios de inclusión y exclusión aplicados durante el tamizaje se alinearon con la estrategia PICOS (Población, Intervención, Comparación, Resultados, Tipo de estudio) y se presentan de manera integral en la Tabla 2.

Tabla 1. *Estrategias de búsqueda empleadas en las principales bases de datos (ejemplo)*

Base de Datos	Estrategia de Búsqueda (Palabras Clave)	Filtros Aplicados
Scopus	TITLE-ABS-KEY ("artificial intelligence" OR "machine learning" OR "chatbot") AND TITLE-ABS-KEY ("mental health" OR "depression" OR "anxiety")	- 2022-2025 - Acceso abierto - Países de ALC especificados - Áreas: Neurociencia, Ciencias de la Computación, Medicina, Psicología - Artículos y Revisiones

Nota. La búsqueda se realizó octubre de 2025. ALC = América Latina y el Caribe. Las demás bases siguieron un patrón metodológico equivalente. Fuente: Elaboración propia.

Para la gestión y depuración de la bibliografía, se empleó el software Zotero. Inicialmente, se aplicó un script personalizado en Python, ejecutado en el entorno Google Colab, para la eliminación de duplicados exactos. Posteriormente, se utilizó la plataforma Rayyan para la detección y exclusión de duplicados por similitud alta, obteniéndose un total de 1.048 estudios únicos para la fase de tamizaje.

Tabla 2. *Criterios de inclusión y exclusión para la selección de estudios*

Categoría	Criterios de Inclusión	Criterios de Exclusión
Población	Estudios centrados en seres humanos con o en riesgo de trastornos mentales (ej. depresión, ansiedad).	Estudios con modelos animales, células o condiciones físicas no relacionadas (ej. quemaduras, cardiopatías).
Intervención	Uso de herramientas de IA (ej. ML, PLN, chatbots, DL) para apoyo, diagnóstico o monitoreo terapéutico.	Aplicaciones de IA en contextos no terapéuticos (ej. marketing, finanzas, hardware).
Resultados	Métricas de eficacia clínica, usabilidad, precisión diagnóstica o viabilidad técnica.	Cartas al editor, editoriales, opiniones o revisiones puramente narrativas.
Contexto	Estudios realizados en cualquier país, con mención explícita a América Latina o aplicabilidad al contexto.	Estudios sin aplicabilidad al ámbito de la salud mental o la práctica terapéutica.
Idioma y Fecha	Artículos en español o inglés, publicados entre enero de 2020 y mayo de 2025.	Artículos en otros idiomas o fuera del rango temporal definido.

Nota. Fuente: Elaboración propia.

El proceso de selección se llevó a cabo en dos fases. Primero, se realizó un tamizaje de títulos y resúmenes basado en los criterios predefinidos. En esta fase, se excluyeron 992 estudios por no cumplir con los criterios de inclusión, presentar insuficiencia metodológica o realizar una mención solo superficial de la IA y la salud mental. Segundo, se recuperaron y evaluaron a texto completo los 56 artículos restantes, confirmando su idoneidad para la síntesis final. La Imagen 1 presenta el diagrama de flujo PRISMA 2020, el cual detalla de manera gráfica el proceso completo de identificación, tamizaje, elegibilidad e inclusión de los estudios.

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Imagen 1. *Diagrama de Flujo PRISMA*

Nota. Fuente: Elaboración propia.

La extracción de datos se realizó de forma semiautomatizada. Se utilizaron herramientas de procesamiento masivo de texto para generar resúmenes estructurados de los artículos seleccionados, lo que facilitó su posterior categorización y análisis temático. Las variables extraídas incluyeron: tipo de estudio, país de origen, tecnologías de IA utilizadas, trastornos mentales abordados, arquitecturas tecnológicas descritas y limitaciones reportadas por los autores. Este procedimiento sistemático permitió una caracterización robusta y reproducible del corpus de literatura analizado.

Resultados

El análisis de los 56 estudios incluidos permitió caracterizar el panorama del uso de la Inteligencia Artificial (IA) como apoyo terapéutico en salud mental, con hallazgos relevantes para el contexto global y, específicamente, para América Latina. Los resultados se presentan a continuación, alineados con los objetivos de la investigación.

Caracterización de la Literatura Incluida

El análisis exploratorio incluyó estudios publicados entre 2020 y 2025, con predominancia de investigaciones provenientes de China, Estados Unidos, Brasil, Colombia, México y Ecuador. En cuanto al tipo de estudio, se observó una distribución equilibrada entre estudios experimentales (39%), observacionales (32%) y revisiones sistemáticas (29%). Un análisis temporal mostró un incremento notable en la publicación de estudios a partir de 2022, coincidiendo con la expansión global de los modelos de lenguaje grandes (LLMs) y un mayor interés post-pandemia en las herramientas digitales de salud mental.

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La Tabla 3 presenta una muestra representativa de seis estudios incluidos en la revisión, para ilustrar esta diversidad de enfoques y procedencias.

Tabla 3. *Muestra representativa de estudios incluidos en la revisión sistemática*

Autor / Año / País	Tipo de estudio	Trastorno abordado	Tecnologías IA	Hallazgo principal
Santamaría-García et al., 2023 – Colombia	Observacional	Depresión, Ansiedad	ML (Elastic Net, LASSO, Ridge)	Factores sociales y de salud mental influyen más que edad/sexo en envejecimiento saludable en ALC.
Entenberg et al., 2023 – Argentina	Experimental	Problemas de conducta	Chatbot, NLP	Chatbot enseñó habilidades de elogio; no hubo diferencias significativas en conducta disruptiva.
Gaona et al., 2025 – Ecuador	Observacional	Trastorno Bipolar	Random Forest, SVM	Random Forest alcanzó 89% de precisión en clasificación de TAB I/II vs. depresión unipolar.
Ma et al., 2023 – China	Experimental	TEA, Depresión mayor	Deep Learning, GNN	Modelo de grafos dinámicos multi-escala superó métodos previos en clasificación de TEA y TDM con fMRI.
Čukić et al., 2020 – España	Revisión sistemática	Depresión	ML	Revisión de EEG en reposo; necesidad de datasets más grandes y procedimientos sistemáticos para diagnóstico clínico.
Weintraub et al., 2022 – EE. UU.	Observacional	Depresión, Bipolar	ML, SVM	Uso del lenguaje en habla espontánea predijo síntomas depresivos en adolescentes de alto riesgo.

Nota. La tabla presenta una muestra representativa de los estudios incluidos; el listado completo (n=56) está disponible bajo solicitud al autor de correspondencia. ML: Machine Learning; NLP: Natural Language Processing; SVM: Support Vector Machine; TAB: Trastorno Afectivo Bipolar; TEA: Trastorno del Espectro Autista; TDM: Trastorno Depresivo Mayor; GNN: Graph Neural Networks; EEG: Electroencefalograma; fMRI: Functional Magnetic Resonance Imaging. Fuente: Elaboración propia asistida con IA: Copilot.

Tecnologías y Trastornos Abordados

El análisis de las tecnologías de IA utilizadas reveló que el machine learning fue la más frecuente (67.9%), seguida por deep learning (21.4%), support vector machines (14.3%) y random forest (14.3%). Los trastornos mentales más abordados fueron depresión (44.6%), ansiedad (32.1%), esquizofrenia (8.9%), trastorno del espectro autista (TEA, 8.9%) y trastorno afectivo bipolar (TAB, 7%). En la imagen 2 se puede ver esta distribución, en contraste con ALC. Por otra parte, la intersección entre estas tecnologías y los trastornos permitió identificar patrones de uso técnicamente fundamentados, los cuales se sintetizan en la Tabla 4.

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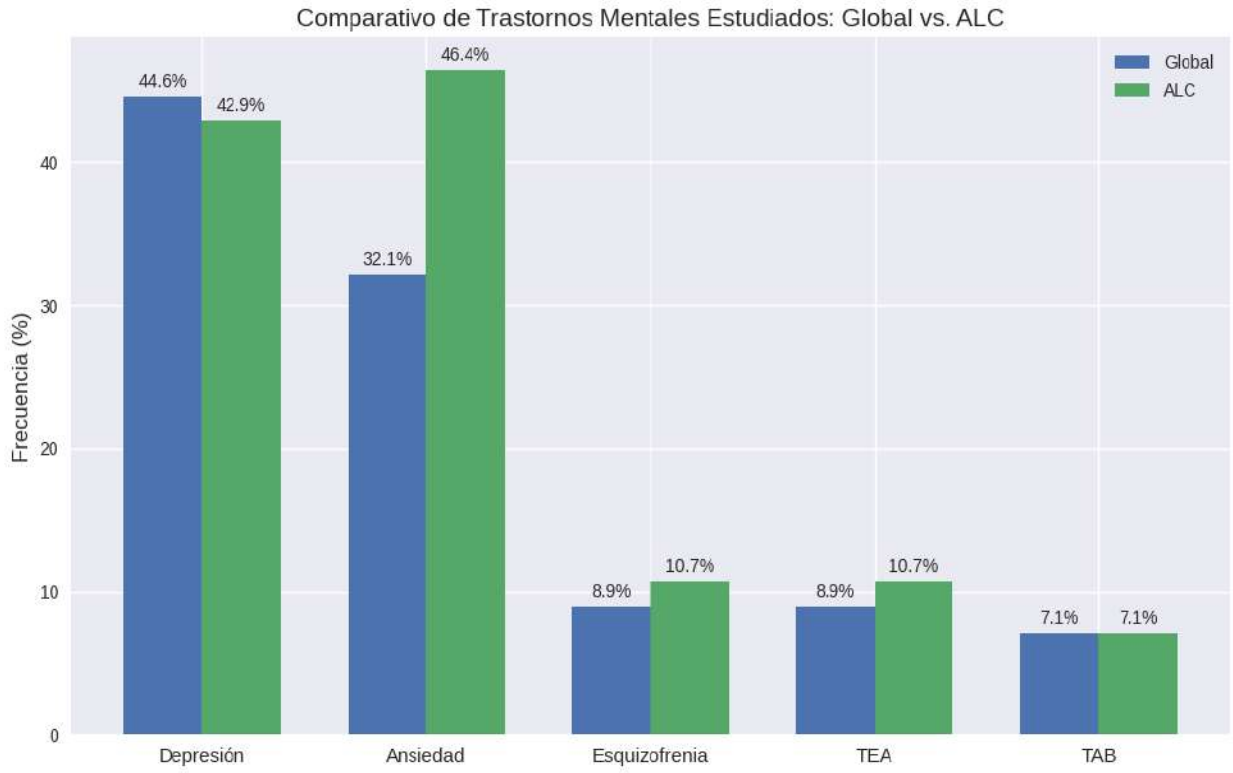
Imagen 2. *Comparativo de trastornos más estudiados*



Nota. Fuente: Elaboración propia asistida con IA: Copilot.

Consideraciones Éticas en la Literatura Global

El análisis de los aspectos éticos reveló que solo el 34% de los estudios incluidos abordaba consideraciones éticas de manera explícita. Los temas principales identificados fueron la privacidad de los datos, la gestión de sesgos algorítmicos y la mención de aprobaciones por comités de ética institucionales. Este hallazgo evidencia una brecha significativa entre el desarrollo tecnológico y la reflexión ética en la literatura revisada.

Hallazgos en el Contexto Latinoamericano

Un análisis focalizado en la literatura de América Latina y el Caribe (ALC), procedente de 7 países con Brasil a la cabeza (35.7%), Colombia (21.4%) y México (17.9%), reveló un panorama distintivo. La imagen 3 compara esta distribución, donde se puede observar que los estudios de la región muestran una clara preferencia por el desarrollo y aplicación de soluciones basadas en Machine Learning (75.0%) y Procesamiento de Lenguaje Natural (21.4%), priorizando la accesibilidad y la escalabilidad. Se observa un enfoque prominente en el uso de chatbots terapéuticos (ej. Psico Bot en Brasil) y el análisis de datos de redes sociales (Twitter/X) y señales de voz para la detección de depresión y ansiedad, utilizando algoritmos como Random Forest, SVM y XGBoost.

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Tabla 4. *Tecnologías de IA aplicadas a trastornos de salud mental*

Trastorno Mental	Tecnologías de IA más utilizadas	Aplicación principal	Consideraciones para América Latina
Ansiedad & Depresión	ML supervisado, PLN, Chatbots	Detección, monitoreo y apoyo conversacional	Ideal por su escalabilidad; necesita adaptación cultural y datos locales.
Esquizofrenia & Trastorno Bipolar	Deep Learning, SVM, Random Forest, Análisis multimodal (voz, EEG)	Diagnóstico temprano, análisis de patrones complejos	Alta complejidad técnica; requiere validación clínica rigurosa.
Trastorno del Espectro Autista (TEA)	Visión por computadora, Deep Learning	Reconocimiento de patrones conductuales	Herramienta de apoyo al diagnóstico; desafíos éticos en la interpretación.
Trastornos de Sueño & TEPT	Modelos híbridos, Clustering, PLN	Monitoreo fisiológico, análisis de narrativas	Enfoque emergente; potencial para telemedicina.

Nota. PLN: Procesamiento de lenguaje natural. Fuente: Elaboración propia.

Limitaciones Identificadas

La literatura regional también expuso limitaciones críticas y recurrentes: una ausencia casi total de validación clínica longitudinal, la dependencia de modelos entrenados con datos extranjeros que no capturan la diversidad sociolingüística latinoamericana, y una brecha regulatoria significativa. Específicamente, se identificó que menos del 10% de los estudios latinoamericanos realizaron seguimientos a largo plazo para evaluar la sostenibilidad de los beneficios terapéuticos, y ninguno de los chatbots revisados mencionó la existencia de protocolos predefinidos para el manejo de crisis suicidas, una omisión ética de gran relevancia.

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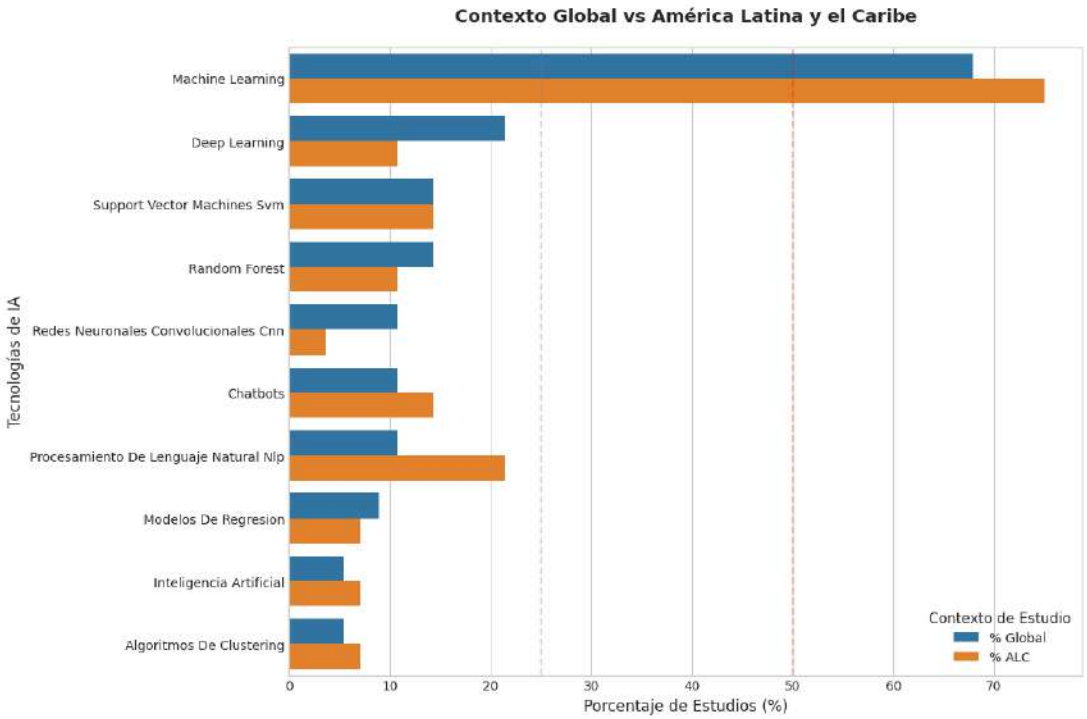
Imagen 3. *Comparativo de Tecnologías de IA*



Nota. Fuente: Elaboración propia.

Discusión

Esta revisión sistemática evidencia que la Inteligencia Artificial (IA) está consolidándose como un conjunto de herramientas versátil para el apoyo terapéutico en salud mental, con un panorama de aplicación que varía significativamente entre el contexto global y la realidad latinoamericana. Los hallazgos de este trabajo no solo confirman la viabilidad técnica de estas soluciones, sino que también delinean con precisión las brechas críticas que deben superarse para una implementación ética y efectiva, especialmente en América Latina.

El predominio del machine learning y, en particular, de los chatbots y el Procesamiento de Lenguaje Natural (PLN) para abordar la depresión y la ansiedad a nivel global (Cruz-González et al., 2025; Pavlopoulos et al., 2024), se explica por la alta prevalencia de estos trastornos y la facilidad para obtener datos digitales que permiten entrenar modelos predictivos y conversacionales. Sin embargo, este estudio revela que en América Latina esta tendencia se acentúa hacia un pragmatismo tecnológico. La marcada preferencia regional por el machine learning y el PLN sobre arquitecturas más complejas como el deep learning no refleja una falta de capacidades, sino una respuesta ingeniosa a restricciones contextuales. Este hallazgo se alinea con la observación de Gutiérrez et al. (2024) sobre la necesidad de priorizar la escalabilidad y el bajo costo en entornos con recursos limitados. El enfoque latinoamericano en el análisis de redes sociales y señales de voz utilizando algoritmos de código abierto constituye una estrategia para sortear la escasez de profesionales y llegar a poblaciones remotas, un desafío estructural ampliamente documentado (OPS, 2025).

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No obstante, este pragmatismo conlleva riesgos significativos. La dependencia de modelos entrenados con datos de poblaciones no latinoamericanas, identificada en esta revisión, plantea serios problemas de sesgo algorítmico y falta de pertinencia cultural, una limitación que Torous y Blease (2024) ya habían señalado como una barrera crítica para la equidad en la salud digital. La ausencia de validación clínica longitudinal y de protocolos para el manejo de crisis suicidas en los chatbots de la región es, quizás, la omisión más grave. Esta falta de robustez ética y clínica convierte a herramientas potencialmente útiles en intervenciones de riesgo, exponiendo a una población vulnerable a daños potenciales en un vacío regulatorio.

La brecha ética identificada, en la que solo un tercio de los estudios globales abordan consideraciones éticas, es consistente con los hallazgos de Tornero-Costa et al. (2023), quienes alertaron sobre fallas metodológicas y de calidad en la investigación de IA en salud mental. Este trabajo corrobora que, si bien el avance tecnológico es acelerado, la reflexión sobre privacidad, consentimiento informado y equidad no avanza al mismo ritmo. En el contexto latinoamericano, esta brecha se amplía debido a la falta de marcos regulatorios específicos, dejando a los usuarios desprotegidos y a los desarrolladores sin directrices claras.

En conclusión, esta discusión subraya que el principal valor de la IA en salud mental para América Latina no reside solamente en la adopción de tecnologías de vanguardia, sino en el desarrollo de un ecosistema propio que combine el ingenio técnico-pragmático con una validación clínica rigurosa, una base de datos local representativa y un marco ético-robusto. La promesa de estas herramientas se cumplirá solo cuando la innovación tecnológica y la garantía de derechos avancen de la mano.

Conclusiones

Esta revisión sistemática permitió analizar el estado del uso de la Inteligencia Artificial (IA) como herramienta de apoyo terapéutico en salud mental, con énfasis en América Latina, cumpliendo así con los objetivos planteados. Se identificó que el machine learning, el procesamiento de lenguaje natural y los chatbots constituyen las tecnologías más empleadas a nivel global, con una aplicación predominante en los trastornos de depresión y ansiedad.

En el contexto latinoamericano, se constató la viabilidad de un enfoque pragmático, caracterizado por el uso intensivo de machine learning y el análisis de datos de fuentes accesibles como redes sociales y señales de voz. Sin embargo, este enfoque se enfrenta a limitaciones críticas, como la ausencia de validación clínica longitudinal, la dependencia de datos foráneos que introducen sesgos algorítmicos y una brecha regulatoria y ética significativa, particularmente en el manejo de situaciones de crisis.

El estudio contribuye al campo al proporcionar un mapa tecnológico y crítico que evidencia la desconexión entre el desarrollo global y las necesidades regionales. Como aplicaciones prácticas, se recomienda el diseño de soluciones que prioricen la interoperabilidad con los sistemas de salud pública y la creación de conjuntos de datos locales para entrenar modelos representativos.

Para futuras investigaciones, se identificaron tres líneas prioritarias: 1) la realización de ensayos clínicos controlados en entornos de atención primaria en América Latina; 2) el desarrollo y validación de marcos éticos específicos para IA en salud mental, tomando como referencia regulaciones internacionales; y 3) el fomento de investigaciones interdisciplinarias que integren la ingeniería de sistemas, la ciencia de datos y

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la bioética para diseñar intervenciones tecnológicamente robustas, clínicamente validadas y éticamente responsables.

Limitaciones del Estudio

Si bien esta revisión sistemática se condujo siguiendo los lineamientos PRISMA, se reconocen algunas limitaciones. El análisis se restringió a estudios publicados en inglés y español entre 2020 y 2025, lo que pudo excluir investigaciones relevantes en otros idiomas o contextos. Además, la categorización temática dependió de la información disponible en los resúmenes y textos completos, lo que puede generar sesgos interpretativos. Futuras revisiones podrían ampliar el alcance temporal y lingüístico, así como incorporar validaciones clínicas y participativas en el análisis de tecnologías emergentes.

Agradecimientos

El autor desea expresar su gratitud al docente Tobías Parodi, líder del semillero de investigación Innovarium, por presentarle la oportunidad de participar en el congreso CITIE 2025. Al Dr. Fernando Vera y REDIIE, por aceptar la ponencia en el congreso y brindar la oportunidad de presentar esta publicación. Y a sus compañeros de la Universidad por el apoyo y los espacios concedidos para dedicar tiempo a la investigación.

El presente manuscrito es una ampliación y corrección sustancial del trabajo presentado en el congreso CITIE 2025 bajo el título "Inteligencia Artificial como herramienta de apoyo terapéutico en salud mental: Perspectiva tecnológica en América Latina y Colombia".

Declaración de Intereses

El autor principal declara que no existe ningún conflicto de intereses relacionado con esta investigación.

Contribución de Autoría

Durante la preparación de este trabajo, el autor utilizó a DeepSeek como herramienta de asistencia para mejorar la legibilidad, sintetizar información y estructurar contenidos de manera preliminar. Tras el uso de esta herramienta/tecnología, el autor asumió la responsabilidad de revisar y editar el contenido en su totalidad, garantizando la veracidad e integridad de la información publicada y asumiendo la plena responsabilidad intelectual del manuscrito final.

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ORIGINAL ARTICLE

Precision education in the algorithmic age: Toward a conceptual framework for personalized learning in higher education

FERNANDO VERA[1]

https://orcid.org/0000-0002-4326-1660
[1]University of th Basque Country, Spain

Corresponding author: fernandovera@rediie.cl

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Abstract

This article presents the design and implementation of *Kahbom*, a low-cost, game-Precision education in the algorithmic age has gained increasing relevance as higher education institutions seek to respond more effectively to student diversity, learning variability, and evolving demands for personalized teaching. Assisted by artificial intelligence, this emerging approach moves beyond traditional standardization by enabling more adaptive, data-informed, and responsive learning environments. This conceptual analysis examines precision education as a developing educational framework shaped by the integration of artificial intelligence, learning analytics, adaptive systems, and pedagogical decision-making. The article identifies its defining attributes, including personalization, predictive support, timely intervention, and continuous adjustment to learners' needs, progress, and contexts. It also discusses key antecedents, such as technological infrastructure, ethical governance, data literacy, and faculty preparedness, as well as its potential outcomes for engagement, equity,

Introduction

Defining Precision Education: Conceptual foundations and scope

Precision education in the age of artificial intelligence may be understood as an emerging pedagogical framework that draws on AI and machine learning to optimize educational experiences according to the needs and profiles of individual learners. Its central premise is that students do not learn in identical ways, at the same pace, or under the same conditions (Chen et al., 2020; Tapalova et al., 2022). Therefore, educational processes should be sufficiently flexible and responsive to accommodate such variability. Through the use of intelligent systems capable of analyzing patterns in learner performance, behavior, and preferences, precision education supports more refined forms of personalization, enabling tailored instruction, timely feedback, and differentiated learning trajectories (Maghsudi et al, 2021). In doing so, it moves beyond traditional standardized approaches and opens new possibilities for more effective knowledge acquisition, sustained engagement, and context-sensitive learning pathways, particularly within higher education environments shaped by digital transformation.

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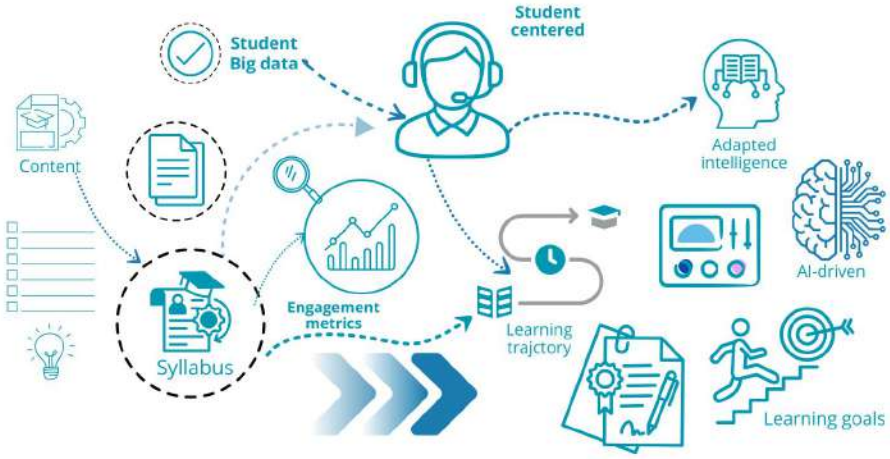
More specifically, precision education can be conceptualized as a data-informed and learner-centered educational approach that seeks to optimize learning, teaching and academic support through the systematic use of large-scale, multidimensional student data. Such data may derive from academic records, assessment results, engagement patterns, behavioral interactions with digital platforms, response times, learning trajectories, trainees' unique learning styles (Coates, 2025) and other indicators generated across students' educational experiences. Within this framework, the purpose is not merely to accumulate information, but to transform these diverse data streams into pedagogically meaningful insights that enable more adaptive, timely, and personalized forms of intervention. In other words, AI-driven precision education provides personalized learning paths, real-time feedback and targeted interventions (Vera, 2024). Accordingly, precision education may be understood as the pedagogical translation of student big data into informed educational action aimed at improving learning effectiveness, strengthening support mechanisms, and fostering student success. However, its significance lies not in datafication itself, but in the ethical, critical, and human-centered interpretation of data in ways that enhance, rather than displace, professional judgment and the relational dimensions of education (Figure 1).

Figure 1. *AI-driven precision education*



Source: Own elaboration.

From standardization to personalization

The shift from standardization to personalization has gained prominence because one-size-fits-all models often struggle to address the heterogeneity of learners in contemporary higher education. Standardized approaches have historically been associated with uniform curricula, fixed pacing, and common assessment structures designed for efficiency and comparability. Yet such models frequently overlook differences in students' prior knowledge, motivation, interests, sociocultural backgrounds, and learning trajectories. In contrast, personalized learning foregrounds the learner's needs, potential, and context, treating education as a more responsive and flexible process rather than a uniform delivery system. UNESCO (2012) defines personalized learning as teaching and learning focused on the learner's background, needs, potential, and perception, explicitly framing it as learner-centered education. Similarly, the rising emphasis on personalized learning is often linked to the belief that it may contribute to fairer academic outcomes across students from different social contexts (Sokolowski & Ansari, 2018).

Within this evolving landscape, precision education can be understood as a more data-informed expression of the broader move toward student-centered education. Rather than if all students benefit equally from identical instructional sequences, precision education acknowledges variability as a central feature of learning. This aligns with wider educational reforms that emphasize student agency, co-construction of learning, and pedagogical responsiveness (OECD, 2020). OECD's Learning Compass framework, for example, highlights student agency as a core principle for future-oriented education, suggesting that learners should be active participants rather than passive recipients of instruction. At the same time, personalization has become increasingly connected to adaptive learning environments that use learner data to refine content, pacing, and support. Recent reviews in higher education note that traditional methods are often insufficient for accommodating individual differences, whereas personalized and adaptive approaches show promise for improving engagement and learning outcomes when implemented thoughtfully. In this sense, precision education does not represent a break from student-centered education, but rather an intensification of its commitment to responsiveness, flexibility, and meaningful learner support.

The movement from standardization to personalization is also closely linked to inclusive education. Inclusion requires more than simply widening access. Thus, educational equity entails more than simply providing the same opportunities to every student (Ahmed et al, 2025). It requires recognizing individual needs and ensuring that each learner receives the resources and support necessary to fully develop their potential.; it involves reducing barriers and creating conditions in which diverse learners can genuinely participate and succeed. UNESCO (2020) frames inclusion as the removal of barriers within and beyond educational systems so that every learner has a real opportunity to benefit from education. From this perspective, precision education becomes relevant because it offers mechanisms for identifying learning needs earlier, tailoring interventions more carefully, and supporting students whose trajectories may be obscured by uniform instructional models. However, the promise of personalization must be approached critically. UNESCO (2020) has also stressed that equity and inclusion in higher education depend on fair representation and tailored frameworks that recognize student diversity, not merely on technological innovation. Accordingly, precision education should be situated within an inclusive and ethical agenda: one that uses data and adaptive tools to expand participation and support, while safeguarding human judgment, educational relationships, and sensitivity to context. Personalization, therefore, is most defensible when it serves inclusion rather than efficiency alone.

Precision Education in the Algorithmic Age

Precision education in the algorithmic age may be understood as an emerging educational framework that seeks to respond to learner variability using artificial intelligence, machine learning, and learning analytics (Bhutoria, 2022, Xu, 2025). Rather than treating students as members of a homogeneous group, this approach aims to identify needs, patterns, and risks at a more granular level to support timely and targeted intervention. In this sense, precision education is closely related to personalized learning, as both are concerned with adapting education to the characteristics and progress of individual learners. However, whereas personalized learning represents the broader pedagogical aspiration to tailor educational experiences, precision education may be seen as its more data-informed and analytically driven expression. Auhtours such as Bhutoria (2022) and Tao (2025) have said that AI-supported dashboards and knowledge graphs, as examples of multimodal technologies, enhance precision education by capturing students' learning behaviors and structuring resources in ways that facilitate more tailored teaching.

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From this perspective, precision education does not replace personalized learning but rather operationalizes it within digitally mediated environments, integrating longitudinal data, analytics, and continuous feedback cycles to deliver precise educational interventions that are proactive, timely, and predictive of meaningful outcome (Rajasekaran, 2024; Triola & Burk-Rafel, 2023). Its distinctive contribution lies in the capacity to transform large volumes of student data into pedagogically meaningful insights that can inform adaptive learning, feedback, pacing, and support. In AI-supported contexts, algorithms can identify behavioral traces, engagement patterns, and performance indicators that may not be immediately visible through conventional instructional observation. Thus, AI-driven precision education in smart learning environments can be seen as an approach that fosters the regulation of student learning through data-informed feedback and adaptive pedagogical support. Consistent with this view, Coates (2025) contends that precision education should be organized around individual learner needs, thereby minimizing the educational inefficiencies associated with conventional time-based learning structures. In such structures, students may be required to revisit content they have already mastered or progress according to predetermined schedules that do not reflect their actual readiness. Accordingly, person-specific AI models may be better positioned than aggregate models to capture the unique dynamics of learners' trajectories. This connection is especially significant in higher education, where growing student diversity exposes the limitations of one-size-fits-all models and underscores the importance of more responsive, flexible, and individualized approaches to teaching and learning

At the same time, precision education in the algorithmic age should not be reduced to technical optimization, prediction, or automated decision-making alone. AI and machine learning make it possible to identify learner characteristics with greater precision and to deliver more tailored educational content, although important challenges persist regarding student motivation, peer interaction, algorithmic bias, and the diversity of learning experiences (Bhutoria, 2022). Its educational value depends on how algorithmic systems are embedded within human-centered, ethical, and pedagogically sound frameworks. Although precision education enhances the goals of personalized learning by making educational adaptation more targeted and timelier, it also raises important concerns related to transparency, bias, surveillance, and the potential erosion of teacher agency (Alzahrani, 2024; Mst, 2025). For this reason, it is more appropriate to conceptualize precision education as a framework in which algorithmic insights complement, rather than replace, professional judgment. Accordingly, personalized learning provides the pedagogical rationale for attending to learner differences, while precision education offers the analytical means to address such differences with greater specificity and responsiveness.

Main characteristics of AI-driven precision education

The main characteristics of AI-driven precision education are presented below, understood as a data-informed and learner-centered approach aimed at improving the quality, relevance, and timeliness of educational decisions.

1. *Data-informed decision-making:* AI-driven precision education relies on the systematic collection and analysis of multidimensional student data, including academic performance, engagement patterns, behavioral traces, and learning progress.

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2. *Learner-centered personalization:* It seeks to adapt teaching, feedback, resources, and learning pathways to the characteristics, needs, strengths, and difficulties of individual learners.

3. *Granular identification of learner variability:* Through AI and machine learning, this approach enables a more precise recognition of differences in prior knowledge, pace of learning, preferences, risk factors, and support needs.

4. *Timely and targeted intervention:* Precision education supports early identification of learning difficulties and allows educators to intervene at the right moment with more specific and relevant support strategies.

5. *Adaptive learning pathways:* It promotes flexible and dynamic learning trajectories, adjusting content, tasks, and levels of support according to students' progress and evolving needs.

6. *Continuous feedback and monitoring:* AI-assisted systems can provide ongoing feedback to both students and educators, making learning processes more visible and enabling continuous pedagogical adjustment.

7. *Predictive capacity:* By detecting patterns in student data, AI can help anticipate potential outcomes such as disengagement, low performance, or dropout risk, thereby improving preventive action.

8. *Integration of multimodal data:* AI-driven precision education often draws on diverse data sources, such as assessment results, platform interactions, attendance, participation, and digital learning behaviors.

9. *Enhanced pedagogical responsiveness:* This approach strengthens educators' ability to make informed and context-sensitive decisions by combining technological insights with professional judgment.

10. *Commitment to inclusion and equity:* When implemented responsibly, precision education can help identify hidden learning needs and support more inclusive practices by responding to student diversity more effectively.

11. *Human-centered interpretation:* Although AI plays an important role, educational decisions should not depend on automation alone. Human interpretation remains essential for ensuring pedagogical relevance, fairness, and contextual understanding.

12. *Ethical and responsible use of data:* A core characteristic of AI-driven precision education is the need for privacy protection, transparency, bias awareness, and accountability in the use of student data and algorithmic systems.

Taken together, these characteristics suggest that AI-driven precision education represents more than the incorporation of advanced technologies into teaching and learning. Rather, it reflects a shift toward a more responsive, evidence-informed, and learner-sensitive educational model in which instructional decisions are increasingly guided by meaningful data and supported by intelligent systems. Its defining value lies in

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its capacity to recognize learner variability with greater accuracy, provide timely and targeted support, and promote more adaptive and inclusive learning pathways. At the same time, its effectiveness depends on the responsible interpretation of data, the preservation of human judgment, and a clear commitment to educational equity and ethical practice. In this sense, AI-driven precision education should be understood not as a substitute for pedagogy, but as a framework that can strengthen pedagogical action by making it more informed, contextualized, and responsive to the complex realities of contemporary higher education.

Methods and Materials

This study was conducted through a conceptual analysis aimed at examining the theoretical and pedagogical foundations of AI-driven precision education. This approach contributes to the development of a robust theoretical foundation that is highly valuable for subsequent empirical research (Heinonen & Gruen, 2024). Conceptual analysis may be understood as a systematic process of inquiry intended to clarify and define a concept by identifying its essential attributes, constitutive components, and related elements within a given disciplinary field.

More specifically, the conceptual analysis was based on the review and synthesis of academic literature on precision education, personalized learning, and the integration of artificial intelligence into the teaching–learning process in higher education. The selection of the literature was guided by the aim of identifying conceptual contributions related to AI-driven precision education, its pedagogical foundations, and its implications for the preparation of professionals for the 21st century. The information was subsequently organized into subtopics to facilitate a clearer and more coherent understanding of the concept under examination.

Conclusions

Precision education in the algorithmic age may be understood as an emerging educational framework that strengthens the shift from standardized instruction toward more personalized, adaptive, and learner-centered forms of teaching and learning in higher education. As discussed throughout this conceptual analysis, its value lies not merely in the use of artificial intelligence or learning analytics, but in the pedagogical capacity to translate diverse student data into timely, context-sensitive, and meaningful educational action.

This article has shown that AI-driven precision education is characterized by data-informed decision-making, granular recognition of learner variability, adaptive learning pathways, continuous feedback, predictive support, and targeted intervention. At the same time, its educational relevance depends on maintaining a human-centered orientation in which algorithmic systems complement, rather than replace, teacher agency and professional judgment. In this sense, precision education should be viewed not as a purely technological innovation, but as a pedagogical and ethical framework for improving responsiveness to student diversity in contemporary higher education.

A central conclusion of this analysis is that precision education has significant potential to contribute to inclusion, equity, engagement, and academic success when implemented responsibly. However, such potential is conditional upon the existence of key antecedents, including adequate technological infrastructure, faculty preparedness, data literacy, ethical governance, and critical awareness of issues

such as surveillance, bias, privacy, and transparency. Without these conditions, the promise of personalization may be reduced to technical efficiency rather than meaningful educational improvement.

Therefore, precision education in the algorithmic age should be conceptualized as a refined pathway toward more inclusive and context-sensitive learning environments, while remaining firmly grounded in pedagogical intentionality and ethical responsibility. Future research should move beyond conceptual clarification to examine how this framework is enacted in practice across diverse higher education settings, disciplines, and student populations. Empirical studies are needed to assess its actual impact on learning outcomes, student support, and educational equity, as well as to explore how educators can be better prepared to work critically and effectively with AI-assisted systems.

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Notas Finales

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Nuestra revista se publica tiene una periodicidad trimestral. Nuestro objetivo es mostrar las principales tendencias en educación y ayudar a diseminar las experiencias metodológicas del profesorado de educación primaria, secundaria y terciaria, a nivel nacional e internacional, permitiendo compartir sus mejores prácticas (*benchmarking*) de manera de potenciar y apalancar las competencias del estudiantado de cara a los desafíos del siglo XXI.

Para lograr nuestro objetivo, hemos definido las siguientes secciones principales: *Tendencias en educación, Experiencias docentes, Gestión educacional y Entrevistas.* Estas secciones serán desarrolladas con rigor académico, enriquecidas con los valiosos aportes experienciales del profesorado y dispuestas en la revista, según las necesidades editoriales. De este modo y teniendo como foco la construcción interdisciplinar del pensamiento pedagógico, ***Transformar*** busca el análisis de teorías y enfoques metodológicos de aprendizaje-desarrollo, la reflexión académica, la diseminación de conocimientos y el intercambio generoso de experiencias educativas. En este contexto, ***Transformar*** ofrece un espacio para el intercambio, la diseminación y promoción de la educación inclusiva y sostenible, relevando el paradigma del aprendizaje permanente (*life-long learning*) y el cuarto Objetivo de Desarrollo Sostenible (ODS 4) de las Naciones Unidas.

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