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TRACKER UNA HERRAMIENTA PARA COMPRENDER FENÓMENOS FÍSICOS EN ESTUDIANTES DIAGNOSTICADOS EN LA I. E. CARACAS MEDELLÍN

TRACKER A TOOL FOR UNDERSTANDING PHYSICAL PHENOMENA IN STUDENTS DIAGNOSED AT THE CARACAS MEDELLÍN EDUCATIONAL INSTITUTION

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Resumen

En este artículo se exponen los resultados obtenidos en un estudio de caso con dos estudiantes diagnosticados de la I. E. Caracas de la ciudad de Medellín que hacen parte del semillero de investigación (CASFI). El objetivo era investigar si la utilización del programa Tracker, que es un programa de libre descarga para hacer análisis y modelado de videos en física a partir de un video grabado de la situación mecánica, servía para comprender dichos fenómenos en estudiantes con discapacidad intelectual. La metodología es de un enfoque cualitativo observando si ellos con este recurso eran capaces de interpretarlo, esta tarea tenía un propósito de estudio descriptivo intentando ver si les permitía distinguir características de movimiento y de tipo intrínseco para ver la eficacia de la utilización de esta herramienta tecnológica. Los resultados de utilizar este Software fueron satisfactorios en el sentido que desarrollo en los chicos compresión de los dos temas estudiados, además permitió identificar que en los estudiantes se dio comprensión de los dos fenómenos analizados. Tracker por ser un programa que permite la repetición ayuda a la comprensión de situaciones físicas con enfoque STEM + H y al desarrollo del pensamiento crítico en los estudiantes. Se espera que este estudio sea útil a otros investigadores que deseen replicar esta técnica a otros estudiantes que tengan otros tipos de diagnósticos cognitivos.

Palabras clave: Diagnosticados, Discapacidad intelectual, DUA, PIAR, Tracker.

Abstract

This article presents the results obtained in a case study with two students diagnosed at I. E. Caracas from the city of Medellín who are part of the physics research group (CASFI). The objective was to investigate whether the use of Tracker, a free downloadable program for analyzing and modeling physics videos based on a recorded video of the mechanical situation, helped students with intellectual disabilities to understand these phenomena. The methodology is qualitative, observing whether they were able to interpret it with this resource. This task had a descriptive study purpose, attempting to see if it allowed them to distinguish characteristics of movement and intrinsic type to see the effectiveness of its use as a technological tool. The results of using this software were satisfactory in the sense that it developed the students' understanding of the two topics studied and also allowed us to identify that the students understood the two phenomena analyzed. Tracker, as a program that allows repetition, helps reinforce concepts in physical situations with a STEM + H approach and promotes the development of critical thinking in

students with intellectual disabilities. It is hoped that this study will be useful to other researchers who wish to replicate this technological aid for other students with other types of cognitive diagnoses.
Keywords: Diagnosed, Intellectual disability, DUA, PIAR, Tracker.

Sumário

Este artigo apresenta os resultados obtidos em um estudo de caso com dois alunos diagnosticados da I. E. Caracas, na cidade de Medellín, que participam do grupo de pesquisa (CASFI). O objetivo era investigar se o uso do programa Tracker, que é um programa de download gratuito para análise e modelagem de vídeos em física a partir de um vídeo gravado da situação mecânica, ajudava a compreender esses fenômenos em alunos com deficiência intelectual. A metodologia adotada é de abordagem qualitativa, observando se eles eram capazes de interpretar esse recurso. Essa tarefa tinha um propósito de estudo descritivo, tentando ver se lhes permitia distinguir características de movimento e de tipo intrínseco para verificar a eficácia do uso dessa ferramenta tecnológica. Os resultados obtidos com a utilização deste software foram satisfatórios no sentido de que desenvolveu nos alunos a compreensão dos dois temas estudados, além de permitir identificar que os alunos compreenderam os dois fenômenos analisados. O Tracker, por ser um programa que permite a repetição, ajuda na compreensão de situações físicas com enfoque STEM + H e no desenvolvimento do pensamento crítico nos alunos. Espera-se que este estudo seja útil para outros pesquisadores que desejem replicar essa técnica em outros alunos com outros tipos de diagnósticos cognitivos.
Palavras-chave: Diagnosticados, Deficiência intelectual, DUA, PIAR, Tracker.

Introduction

In Colombia, the Ministry of National Education (MEN, 2017) published a document entitled “Technical, administrative, and pedagogical guidelines for the educational care of students with disabilities within the framework of inclusive education.” This 230-page text contextualizes the care of students with disabilities in educational institutions in Colombia. In 2005 and 2006, the MEN (2006) had already produced documents providing guidance on pedagogical actions to serve vulnerable populations with hearing impairments, deafness, blindness, autism, and motor and cognitive disabilities.

Later in 2014, the Ministry of Education (MEN, 2014) issued another document to address the needs of the disabled population with the aim of linking intersectorality in the Colombian education system to ensure effective inclusion and seeking to provide quality education and equal opportunities. This quality education is currently included in the sustainable development goals (UN, 2015). In 2008, Colombia established an online enrollment system called SIMAT, which was implemented as a tool for education secretaries to organize student enrollment in the country. This process also records data that allows for the identification of students with disabilities

In 2013, the Congress of the Republic of Colombia enacted Statutory Law 1618 (Congress, 2013), which states: “Whereby provisions are established to guarantee the full exercise of the rights of persons with disabilities.” This represents progress in the country in terms of care for vulnerable populations. In 2017, the president of the republic issued Decree 1421, which “regulates educational services for people with disabilities within the framework of inclusive education” MEN (2017). This decree establishes the path for serving people with disabilities at the country's three levels of education: preschool, elementary, and middle school. Three of the aspects to highlight within the framework of

this law are reasonable accommodation plans, which are adaptations to the comprehensive assessment system according to the specific needs of each diagnosed student. The other relevant component to mention is Universal Design for Learning (UDL), which are designs for products, environments, and programs to make meaningful experiences accessible.

In Ecuador, the Ministry of Education in 2023 (ME, 2023), in fascicle 6, also addresses education from an inclusive approach by applying the ULDs and establishes parameters for serving the population with specific educational needs, as discussed in the article by (García et al., 2023). Decree 1421 in Colombia establishes individual reasonable accommodation plans (PIAR) as a tool that offers suggests in the teaching-learning process, seeking permanence and promotion in the education system. The guidance document (MEN, 2017) establishes the following strategies for participation and the development of public policy documents: "Systematize successful experiences in the educational care of students with disabilities, which serve as a reference for educational establishments."

In accordance with the legal framework of Colombian legislation, researching innovative teaching practices that benefit the diagnosed population in one way or another is a challenge that educators face in their daily work when they have students reported in the SIMAT in their classrooms. In 2020, technical, administrative, and pedagogical guidelines were issued for the educational care of students with disabilities (MEN, 2020). These guidelines seek to ensure the active participation of students with disabilities in the classroom. The Colombia Aprende website contains documents such as guides, booklets, videos, and meaningful experiences that are useful for serving the population with disabilities (Colombiaaprende, 2004).

The Caracas Educational Institution (IEC) in the city of Medellín has a total of 1,253 students enrolled in SIMAT at its two campuses for the year 2025. Sixty of them have diagnostic reports in different grades, representing 4.8% of the population. However, these are only the students reported to SIMAT. Many students are not reported because their guardians have the supporting documents but do not file a report to avoid stigmatizing their children. Others simply do not take their children to be tested by support professionals because they do not admit that their children have learning difficulties, even if the teacher reports these deficiencies. In the eleventh grade of the IEC, there are a total of four students with diagnoses, three of them with intellectual disabilities and one with Down syndrome.

Given the above, investigating whether software such as Tracker Brown (2007) benefits the disabled population is an interesting pedagogical exercise that can bring multiple benefits to the population with a degree of intellectual disability, as is the case in this study.This study covers the topic of Muñoz's text, which uses GeoGebra, PhET, and Tracker in deaf populations (Muñoz et al., 2024). In addition, Tracker has been researched as a teaching tool in university populations (Plaza et al., 2024) and is an excellent tool for conducting research (Melo et al., 2024) and (Melo et al., 2025).

Methodology

As mentioned, the methodology is qualitative-descriptive (PUCP, 2022) with two of the four 11th-grade students at the IEC in Medellín. The two students collaborating in this study have intellectual disabilities; both have been

diagnosed with mental retardation, and one of them also has attention deficit hyperactivity disorder (ADHD). The first phase was to talk to the students' parents to request their authorization for their children to participate in the research, explaining the potential advantages of learning to use software such as Tracker. Then, the students were told about the methodology and how they would participate in the process. This phase was carried out at the end of November 2024, with the project set to begin in January 2025.

The second phase of the process was to explain how to use the Tracker program. To do this, a user manual was first developed and posted on the blog (Melo, 2015). This phase took several weeks due to the feedback that needed to be provided to both students. Ensuring that the students understood how to use the program was key to the research. The third phase involved recording a video of the physical situation to be analyzed. The topic chosen was uniform linear motion (ULM), which is characterized by traveling equal distances in equal times, thereby determining the speed of the particle. The students are in 11th grade, but this topic is included in the 10th grade curriculum. Although the topic was explained the previous year, at no time were formulas mentioned to avoid biasing the possible results. The video was recorded with existing, low-cost resources, using a cell phone as the recording device.

To carry out the experiment, a soccer ball was kicked with the foot so that it would move horizontally across a very smooth surface (to avoid friction), and its movement was recorded when the ball passed in front of a board that served as a backdrop. The movement was practiced several times to ensure that the ball moved with MR. The fourth phase consisted of analyzing the recorded video. To do this, the steps outlined in the user manual must be followed, which are: upload the video to the Tracker program using MP4 format, then check the number of frames per second of the video, which can be found in the video properties.

This value must match the one automatically read by Tracker when uploading, and if it is different, it must be changed. Then, in the calibration bar tab, adjust the value to the actual value of the measuring tape used, which must be visible at the time of recording. Once the calibration bar value has been adjusted, the next step is to remove the axes, which will be the reference system from which the measurements will be taken. With these elements, we can now track the point mass, which in this case is the ball with MRU. In this step, as explained, the program must track the movement at all points along the trajectory, and if for some reason the mass is not tracked, this means that the values of the variables cannot be determined and it is necessary to track again or, if necessary, re-record the video. This happened repeatedly, and it was necessary to re-record it because at some points in the trajectory, the ball was no longer tracked by the program because it confused the background, which was the board, with the color of the ball.

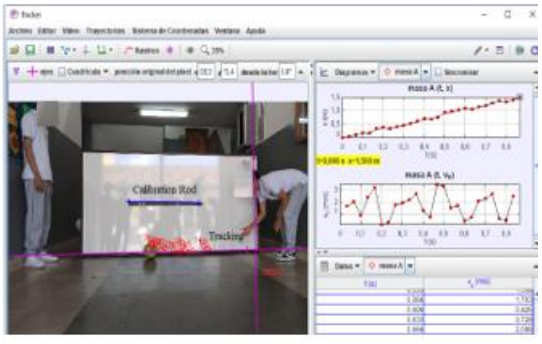

Figure 1. *Tracker program capture of a ball in MRU.*

Source*: Own elaboration*

After completing the video analysis, the students prepared to give a presentation on what they had learned with Tracker to their classmates. They explained the phenomenon they had studied and used Tracker to read data on time and speed.

Figure 2 shows a diagram of the phases followed in this study. There is one aspect that is not mentioned here and will be discussed in the results section, which is the evaluation that was carried out after exposure to the community.

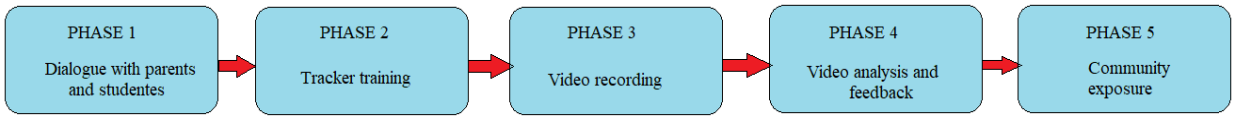

Figure 2. *Diagram of the stages carried out in the research.*

Source*: Own elaboration*

After analyzing uniform linear motion, we decided to study the motion of a mass-spring system in order to measure the period of motion and see the possible advantages of using Tracker software. To do this, the process was repeated from phase 3 in Figure 2 to phase 5, where they also presented their analysis of the motion to their classmates. In both presentations, we were accompanied by administrators and teachers from other areas, and there is a video recording of these presentations. In this case, the mass is unknown, and the spring constant was not disclosed to them. When doing the video analysis, as mentioned, our interest was in analyzing graphs with distance and time variables to determine the period of oscillation, which is the time it takes to complete one oscillation. This topic is for 11th grade, and at no time where they reminded of physical formulas. The objective was to study their understanding of the phenomenon based on graphs obtained in the program.

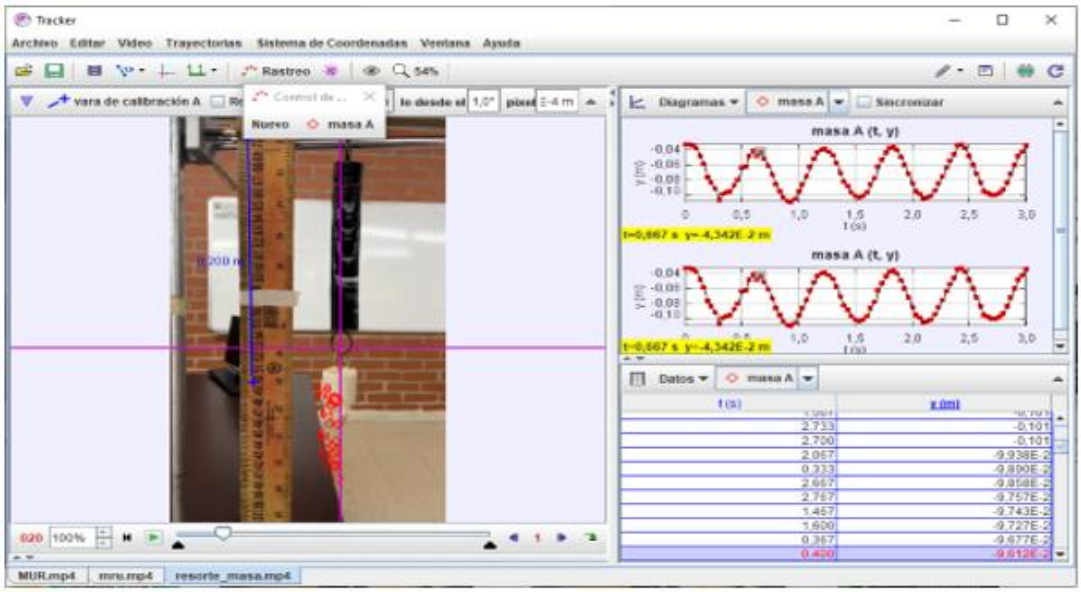

Figure 3. *Screenshot of the Tracker program for a mass-spring system.*

Source*: Own elaboration*

Results and Discussion

The results obtained from this case study allow us to make the following analysis of the use of the Tracker program. In the first case, with the ball with MRU, after recording the video and seeing how they themselves performed the steps to track the movement, the students assured us that Tracker was easy to use, which allows us to confirm that it can be a useful technological tool for other students. In this experiment, they were asked to read the speed value from the data table, which is very easy to obtain in the program; they only had to point to the tab and it showed the value over time.

When this value changed considerably, they themselves concluded that it was not uniform and fast-forwarded the video, and when the value was almost the same, they chose this part to say that it was uniform. In their own words, they said it was the same, and it was clear that they understood what was to be done with this analysis. Achieving this with them is very significant. In the second case, the purpose of the mass-spring system was to see if the graphs provided by the Tracker program allowed them to obtain a variable such as the period. When tracking and obtaining the graphical results, they were told to change the axes because they were interested in vertical distance as a function of time.

Put this way, it seems difficult, but it is simple: just go to the axes and change the variable with a click of the mouse. When they saw the graph and observed the movement, they understood that to find the time in a complete oscillation, they only had to read the value on the time axis from one point to another where the movement was repeated. In this exercise, using the program was more natural because they already knew the steps to follow. The following paragraphs discuss some PIAR strategies (Bogotá Department of Education, 2020) analyzed using Tracker software in students diagnosed with IEC. Curriculum adaptation: Tracker is a STEM+H tool, and with this program, information can be presented differently than in traditional ways, and specific goals can be set for students to achieve. Methodological and resource adjustments: Tracker can be adjusted as a teaching resource tailored to the student's needs, implementing active methodology and allowing for collaboration. Skill development: Tracker helps diagnosed students become more independent.

They can use it as an easy-to-use tool, and it also offers digital literacy by developing skills. Support and monitoring: As Tracker is a free downloadable tool, the process can be supported by families, who play a vital role in supporting people with disabilities. Inclusion throughout the community: Tracker is a program that allows all students to be linked, as in the case studied here, where students belong to the CASFI seedbed and carry out activities with the program (Melo, 2015). Comprehensive pedagogical assessment: Tracker allows you to conduct an assessment where learning barriers can be overcome. Let us now discuss the strategies of the DUA (Unir, 2024) that can be taken into account with the program. Multiple forms of representation:

Tracker is a different option; it is a visual medium that helps students perceive information in a different way. Multiple forms of action and expression: Tracker is a tool that helps students manipulate different materials, because they must record the video and then analyze it with the software, at which point they can express what they have learned. It also helps them develop critical thinking skills in the sense that they can see the evolution of the variables

they record, and students can also see the graphs between variables that are key to interpreting physical phenomena. Multiple ways to get involved: Tracker sparks students' interest, can be used individually or in groups, adapts to different learning paces, and ultimately allows clear goals to be set for students with certain diagnoses. As described in this research, the two situations are different and have specific objectives. It was an exercise designed to assess whether the program effectively served as a STEM +H technological tool for people with disabilities and provided a meaningful experience. The following written test was administered to assess the knowledge acquired, emphasizing whether there was an understanding of the physical phenomena studied. Figure 4 shows a screenshot of the assessment. In addition, it should be mentioned that the students enjoyed it and found it easy to use, which guarantees that this practice can be easily replicated by other teachers with this type of diagnosed population.

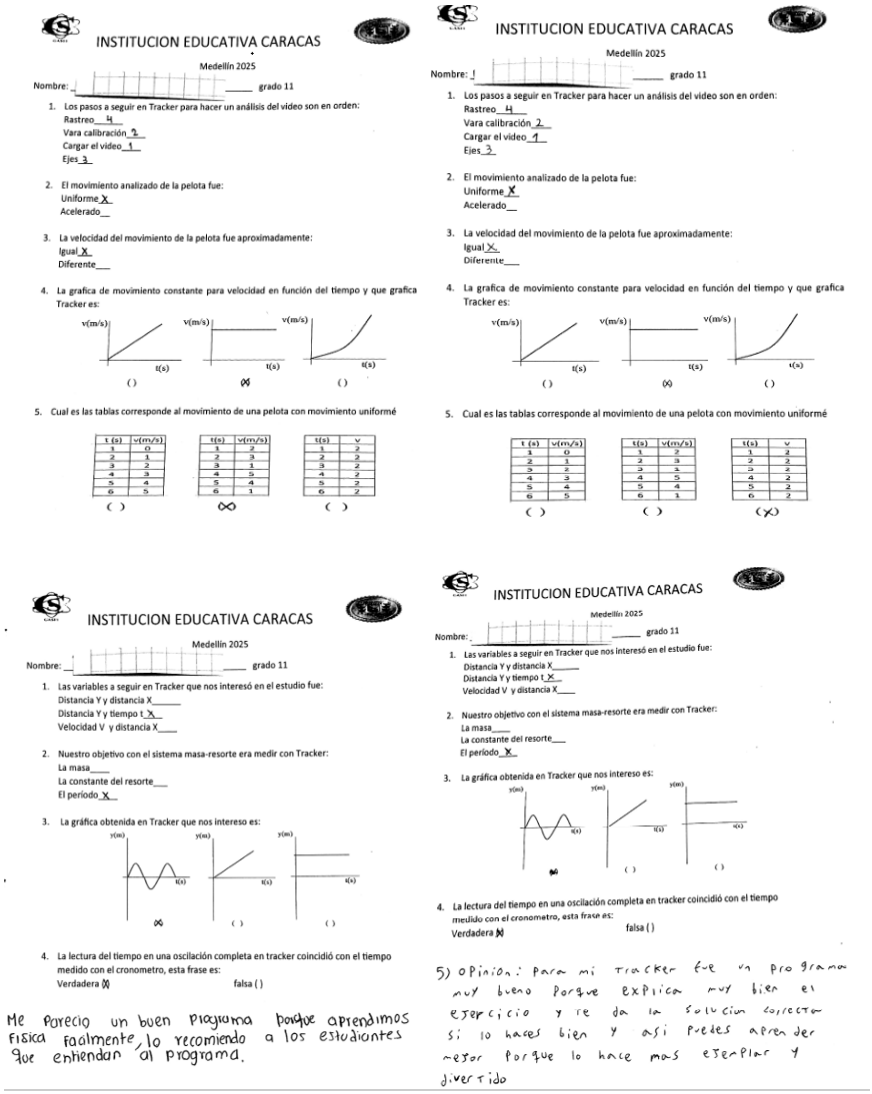

Figure 4. *Photograph of the written test taken after exposure.*

Source*: Own elaboration*

As shown in Figure 4, the assessment contains questions that allow us to evaluate whether there was significant understanding of the two cases. The first focused on observing whether they identified the numerical value of speed as a constant, and in the second case, it was to be able to obtain the period from the graph of distance as a function of time. Both students responded satisfactorily to the test, demonstrating that the program is a useful tool for working with them. This research was presented at the 2nd Interinstitutional Research Conference entitled Transformative Educational Practices: A Path Toward Inclusion, held in the city of Medellín on October 27, 2025. Organized by the Technological University of Antioquia, the Villa de la Candelaria Institution, and the UAI (TdeA, 2025, 4:01:33).

Conclusions

Tracker is a program that can be downloaded for free and is available in two versions, downloadable and online. This case study with students diagnosed with intellectual disabilities concludes that the program is a useful tool for understanding physical phenomena. The research addressed two situations. The first involved the MRU of a ball, where the video was analyzed with Tracker, focusing on the table analysis offered by the data software to read the speed value and see that it is constant, which is the characteristic of the movement. The second case involved a mass-spring system with oscillatory motion, where the analysis changed and was already in the graphs obtained from the motion, which allowed the students to obtain the period of the motion. The study of the two situations was carried out without the use of formulas, focusing only on analyzing the phenomenological characteristics of the motions. Due to its ease of use, Tracker is a technological tool that helps to understand physical concepts, characteristics, and principles in populations with some type of diagnosis, as stated in the text (Muñoz et al., 2024) for deaf-mute populations. It is essential that teachers read the PIARs in advance so that they are aware of the different diagnoses of the student population, which is on the rise in our country.

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Declaraciones éticas y editoriales del artículo
Contribución de los autores (Taxonomía CRediT) Germán Melo Mondragón: conceptualización de la investigación, diseño metodológico, desarrollo del proceso investigativo, análisis formal de los datos, redacción del borrador original del manuscrito, revisión crítica del contenido científico y supervisión general del estudio. Susana Melo Londoño: conceptualización de la investigación, diseño metodológico, desarrollo del proceso investigativo, análisis formal de los datos, redacción del borrador original del manuscrito, revisión crítica del contenido científico y supervisión general del estudio.
Declaración de conflicto de intereses Los autores declaran que no existe conflicto de intereses en relación con la investigación presentada, la autoría del manuscrito ni la publicación del presente artículo.
Declaración de financiamiento La presente investigación no recibió financiamiento específico de agencias públicas, comerciales o de organizaciones sin fines de lucro. En caso de existir financiamiento institucional o externo, este deberá ser declarado explícitamente por los autores en esta sección.
Declaración del editor El editor responsable certifica que el proceso editorial del presente artículo se desarrolló conforme a los principios de integridad científica, transparencia y buenas prácticas editoriales. El manuscrito fue sometido a un proceso de evaluación mediante revisión por pares doble ciego, garantizando la confidencialidad de la identidad de los autores y revisores durante todo el proceso de dictamen académico. Asimismo, el editor declara que el artículo cumple con los criterios científicos, metodológicos y éticos establecidos por la revista.
Declaración de los revisores Los revisores externos que participaron en la evaluación del presente manuscrito declaran haber realizado el proceso de revisión de manera objetiva, independiente y confidencial. Asimismo, manifiestan que no mantienen conflictos de interés con los autores ni con la investigación evaluada, y que sus observaciones y recomendaciones se fundamentan exclusivamente en criterios científicos, metodológicos y académicos.
Declaración ética de la investigación Los autores declaran que la investigación se desarrolló respetando los principios éticos de la investigación científica, garantizando la confidencialidad de los datos y el respeto a los participantes del estudio. En los casos en que la investigación involucre seres humanos, los procedimientos deben ajustarse a los principios éticos establecidos en la Declaración de Helsinki y a las normativas institucionales correspondientes.
Declaración sobre el uso de inteligencia artificial Los autores declaran que el uso de herramientas de inteligencia artificial, en caso de haberse utilizado durante el proceso de investigación o redacción del manuscrito, se realizó únicamente como apoyo técnico para mejorar la claridad del lenguaje o el análisis de información, manteniendo siempre la responsabilidad intelectual sobre el contenido del artículo. Las herramientas de inteligencia artificial no fueron utilizadas como autoras del manuscrito ni sustituyen la responsabilidad académica de los investigadores.
Disponibilidad de datos Los datos que respaldan los resultados de esta investigación estarán disponibles previa solicitud razonable al autor de correspondencia, respetando las normas éticas y de confidencialidad establecidas por la investigación.