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VALIDATING THE USE OF MBLOCK FOR ROBOTICS LEARNING IN VULNERABLE EDUCATIONAL CONTEXTS THROUGH TECHNOLOGICAL READINESS LEVELS

VALIDACIÓN DEL USO DE MBLOCK EN EL APRENDIZAJE DE ROBÓTICA EN CONTEXTOS EDUCATIVOS VULNERABLES A TRAVÉS DE NIVELES DE MADUREZ TECNOLÓGICA

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Validating the use of MBlock for robotics learning in vulnerable educational contexts through technological readiness levels

Validación del uso de MBlock en el aprendizaje de robótica en contextos educativos vulnerables a través de niveles de madurez tecnológica

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ABSTRACT

This study addresses the urgent need to strengthen technological skills among students in under-resourced educational settings. It explores the integration of the STEAM methodology with the MBlock tool as a strategy to enhance students’ capacity for knowledge absorption in programming and robotics. The research followed a four-phase process: identification, assimilation, transformation, and exploitation, supported by a mixed-methods approach that included hands-on workshops, perception surveys, and academic performance assessments.

Findings revealed a notable improvement in students' academic outcomes, rising from an average of 6.8 to 9.1, along with high levels of satisfaction and active participation. The discussion highlights how this approach promotes the required 21st-century skills such as critical thinking, creativity, and collaboration. The results suggest that combining STEAM with accessible technologies like MBlock is an effective and scalable model for fostering inclusive, innovative education in vulnerable learning environments.

Keywords: pedagogy; didactics; innovation; robotics; technological readiness

RESUMEN

En respuesta a la necesidad de fortalecer competencias tecnológicas en contextos educativos vulnerables, esta investigación aplicó la metodología STEAM integrada con la herramienta MBlock para potenciar la capacidad de absorción de conocimiento en estudiantes técnicos. El propósito fue validar su efectividad en el aprendizaje de programación y robótica a través de un enfoque por etapas: identificación, asimilación, transformación y explotación. Se utilizó una metodología mixta, combinando talleres prácticos, encuestas de percepción y análisis del rendimiento académico. Los resultados evidenciaron una mejora significativa en el desempeño estudiantil, de 6.8 a 9.1, así como altos niveles de satisfacción y compromiso. La discusión confirma que la integración de STEAM y MBlock impulsa el pensamiento crítico, la creatividad y el trabajo colaborativo, contribuyendo a una educación más equitativa e inclusiva. Se concluye que esta propuesta es efectiva y replicable para ampliar el acceso a la educación tecnológica en realidades con recursos limitados.

Palabras clave: pedagogía; didáctica; innovación; robótica; madurez tecnológica

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INTRODUCTION

The accelerated pace of technological development continues to reshape modern society, influencing how we communicate, work, and learn (Ouyang & Xu, 2024). In this context, education systems face increasing pressure to adapt and prepare students for a technology-driven world. As Guaña-Moya (2023) emphasizes, equipping learners with digital competencies has become an urgent priority. Moreover, the integration of technology into curricula strengthens technical skills to foster critical thinking, creativity, and problem-solving abilities fundamental for 21st-century citizenship (Haleem et al., 2022).

Despite the growing importance of these competencies, students from vulnerable and low-income communities often encounter systemic barriers to accessing quality instruction in programming and robotics (Sapounidis et al., 2024). These challenges, ranging from limited infrastructure and scarce resources to a shortage of trained educators, significantly restrict opportunities for digital inclusion and professional advancement (Rodríguez et al., 2023). Additionally, conventional pedagogical approaches tend to fall short in engaging these learners, which contributes to low interest and participation in Science, Technology, Engineering, Arts, and Mathematics (STEAM) disciplines (Litardo et al., 2023).

To address these differences, researchers have advocated for the adoption of active and inclusive teaching strategies such as Project-Based Learning (PBL), particularly when combined with visual programming tools (Hernández-Ramos et al., 2021). Platforms like Scratch and MBlock have gained prominence in educational settings due to their intuitive interfaces, which lower the cognitive barrier to entry for students new to programming (Obermüller et al., 2022). These tools encourage experimentation and creativity, allowing learners to apply abstract programming concepts through tangible, hands-on projects. According to Jimenez-Gaona and Maldonado-Gonzalez (2022), early exposure to such tools can significantly enhance students' readiness for future academic and professional challenges.

Moreover, the integration of MBlock into STEAM-based PBL environments has shown promising results in improving student engagement and learning outcomes, especially in underserved contexts (Pérez-Torres et al., 2023). Studies by Abidin et al. (2021) and Noordin et al. (2022) report that low-cost educational robotics kits, when paired with constructivist pedagogies, foster meaningful learning and skill development. These tools also support differentiated instruction and learner autonomy, critical features in diverse classrooms with varying levels of prior knowledge and access to resources. Crnokić et al. (2023) further argue that such platforms contribute to more adaptive, personalized learning environments.

An important consideration in ensuring the sustainable integration of these technologies into school systems is the concept of technological readiness (Chau et al., 2021). One widely recognized model for assessing this is the Technology Readiness Levels (TRLs) framework (Yfanti & Sakkas, 2024), originally developed by NASA and now widely applied across sectors, including education (Olechowski et al., 2020). TRLs propose a structured approach to evaluating an institution's capacity to adopt and scale educational technologies. Rahmat et al. (2022) highlight the importance of aligning institutional readiness, infrastructure, and teacher development to ensure that technological innovations are pedagogically effective and contextually appropriate.

Despite the theoretical value of the TRL model, its practical application in vulnerable educational environments remains underexplored (Maryani et al., 2023). There is a lack of empirical studies that assess how TRLs can guide the phased integration of educational tools like MBlock in schools facing structural inequities. This gap highlights the need for applied research that measures technological adoption by considering the socio-educational dynamics at play in marginalized contexts.

This study aims to validate the use of MBlock as a pedagogical tool for developing competencies in educational robotics among students in vulnerable settings, using the TRL framework as a guiding structure. By evaluating the integration process across different stages of technological readiness, the research aims to generate insights into how educational institutions can effectively adopt low-cost, high-impact tools to foster STEM engagement and reduce the digital divide.

METHODOLOGY

This study utilized a variety of instruments and technological resources to support the teaching of programming and robotics to children from vulnerable backgrounds (Zhai et al., 2024). Central to the intervention was MBlock, a block-based visual programming platform that enables learners to grasp programming and robotics concepts through an intuitive, hands-on approach. To complement this digital tool, accessible robotics kits such as MBot were incorporated, offering students the opportunity to physically construct and program robots (Gaskell et al., 2024). The instructional environment was further supported by computers and projectors to visualize programs, while practical activities were conducted in classrooms equipped with fundamental resources to facilitate learning.

The process of knowledge absorption followed a structured model, beginning with the acquisition phase. This involved identifying and obtaining relevant external knowledge from diverse sources including academic literature, technical reports, and institutional experiences from universities, companies, and community knowledge systems (ethnoknowledge) (Sobrinho, 2025). Acquisition methods were varied but adhered strictly to academic integrity and respect for intellectual property.

Following the acquisition, the assimilation phase focused on the analysis and comprehension of the gathered knowledge (Cobos et al., 2021). This was achieved through multiple activities such as formal courses, workshops, seminars, participation in fairs, and

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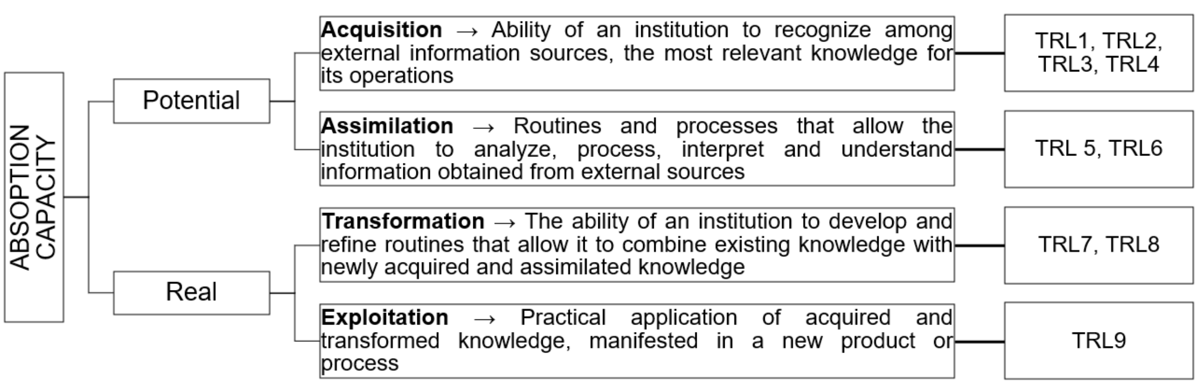
strategic alliances with external entities. These efforts aimed to ensure effective internalization and dissemination of knowledge among educators and stakeholders.

Next, the transformation phase involved adapting the assimilated knowledge to fit the practical contexts of teaching programming and robotics. This stage combined existing experience with new insights, enabling the adoption of innovative technologies and teaching practices (Leon-Roa et al., 2024). Pilot implementations and iterative testing were key to refining methods and ensuring suitability before full integration.

Finally, the exploitation phase explored three avenues for leveraging the transformed knowledge: curriculum updates to enhance student learning, innovations in institutional core functions, and incorporation of novel approaches in outreach or production processes, both internally and in collaboration with external partners (Salvador-Carulla et al., 2024). This comprehensive absorption cycle is visually represented in Figure 1, linking each stage to specific Technology Readiness Levels (TRLs).

Figure 1

Absorption capacity



The implementation of this approach yielded significant educational transformations in local schools (Kohli et al., 2024). Through interactive and collaborative learning, students developed technical competencies and increased their motivation and interest in science and technology. Integrating MBlock into the curriculum facilitated a more intuitive and engaging learning experience. Institutional adoption across various courses ensured that this methodology supported inclusive education aligned with 21st-century learning demands.

Furthermore, the methodology incorporated a validation framework based on technological readiness levels, enabling systematic evaluation of implementation effectiveness at each stage. Progress was monitored through indicators such as student engagement and problem-solving capacity. Complementary qualitative observations during class sessions and quantitative assessment data provided a robust picture of advances in programming, robotics skills, and critical thinking. This iterative feedback loop informed continuous improvements, fostering the achievement of progressively higher levels of technological readiness.

RESULTS

Identification and Acquisition

The initial phase focused on identifying and acquiring knowledge about the MBlock platform and its applicability for teaching robotics and programming within vulnerable educational settings. This process was grounded in a comprehensive literature review that helped establish a solid conceptual framework and informed the selection of suitable pedagogical strategies (Anh et al., 2024). Concurrently, pilot workshops and virtual experiments were conducted to introduce both students and educators to the MBlock environment. Analysis of participation metrics revealed a growing interest in the tool, reflected in high attendance and active engagement during early activities. Survey feedback highlighted that students and teachers alike perceived MBlock as an innovative, accessible resource with strong potential to develop foundational technological skills.

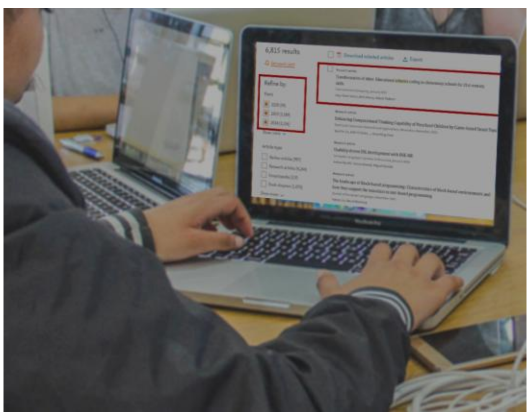
Assimilation

In this stage, emphasis was placed on the assimilation of STEAM concepts through hands-on laboratory experimentation (Khatri et al., 2025). The initiative encouraged the integration of technical and scientific knowledge via programming and robotics projects developed with MBlock, involving diverse courses and subject areas.

Formative assessments and perception surveys documented significant improvements in students' comprehension of STEAM principles and a notable increase in their confidence when applying these concepts practically. Furthermore, enhanced collaboration among students from different disciplines was observed, fostering a richer interdisciplinary learning experience. Figure 2 illustrates the process of searching, collecting, and synthesizing information related to MBlock for course preparation.

Figure 2

Laboratory sessions for the synthesis of MBlock information in scientific databases



Transformation

During the transformation phase, MBlock was implemented at the institutional level, engaging multiple courses and academic programs. This phase sought to translate theoretical knowledge into practical skills through virtual workshops and collaborative projects that integrated various STEAM disciplines, promoting a holistic educational approach (Gavrilas et al., 2024). Figure 3 illustrates the commencement of the course for teaching the *interdisciplinary projects.*

Figure 3

Workshop with students and teachers collaborating on interdisciplinary projects

Continuous monitoring, via evaluations, surveys, and academic performance analyses, enabled iterative refinement of the methodology to optimize learning outcomes. This phase saw a marked increase in student engagement and performance on interdisciplinary projects, alongside improved capacity to tackle complex problems. Figure 4 shows the training and solutions provided by teachers to the assistants.

Figure 4

Teachers' review of progress and solutions during institutional rollout

Exploitation

The final phase involved the full integration of MBlock into the school curriculum, with comprehensive interdisciplinary projects that combined multiple STEAM domains. A robust

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system of ongoing monitoring was established to continually assess and enhance pedagogical strategies, ensuring responsiveness to the evolving needs of students and teachers. Figure 5 evidence the accompaniment of the instructors solving concerns during the individual evaluation.

Figure 5

Supervised individual evaluations conducted during practical activities

Outcomes from this stage demonstrated that curricular integration of MBlock significantly fostered critical competencies such as creative thinking, problem-solving, and teamwork. Continuous evaluation and responsive feedback mechanisms improved the educational experience and facilitated the dissemination of best practices to other institutions, thereby broadening the project’s impact. Figure 6 illustrates the activities conducted entirely by the beneficiary children, highlighting their acquisition of knowledge in robotics and the development of critical thinking skills in decision-making for their designs.

Figure 6

Autonomous student work showcasing learning outcomes in robotics projects

Qualitative and Quantitative Analysis

Figure 7 illustrates a consistent upward trend in students' academic performance across STEAM-related topics throughout the four implementation phases. During the Identification and Acquisition phase, the initial average score of 4.8 out of 10 improved to 6.2, reflecting a nearly 30% increase. This suggests that early exposure to MBlock sparked interest and initial engagement. As students moved into the Assimilation phase, characterized by hands-on activities and cross-disciplinary learning, the average rose to 7.4, highlighting deeper understanding and confidence. The final stages, Transformation and Exploitation, showed further consolidation of knowledge and skills, with performance reaching 8.9. These results support the effectiveness of a gradual, experiential approach in strengthening both conceptual and practical competencies in STEAM education.

Figure 7

Academic Performance in STEAM Areas

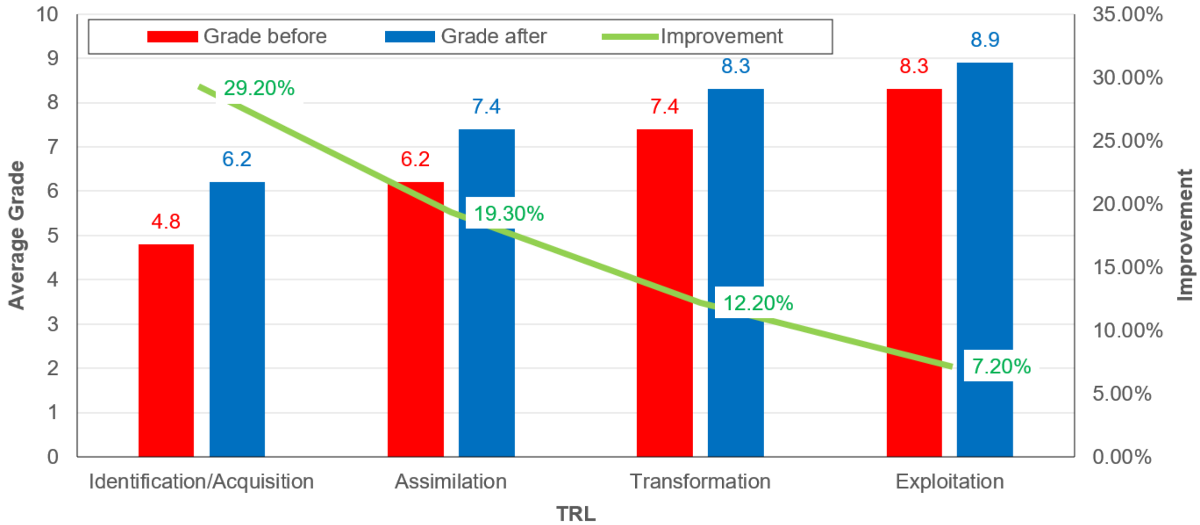

Figure 8a summarizes responses from perception surveys administered to students, using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). The data reflect a strong positive reception of the MBlock-based learning experience. Students reported high levels of engagement (4.6), clarity in using the tool (4.4), and particularly recognized its relevance to their educational development (4.7). Figure 8b shows Teachers' responses, where they echoed this sentiment, noting the methodology's effectiveness (4.6) and increased student motivation (4.5). These high average scores suggest that MBlock was well-received and perceived as a valuable and adaptable teaching resource, reinforcing its potential for long-term integration into educational practice.

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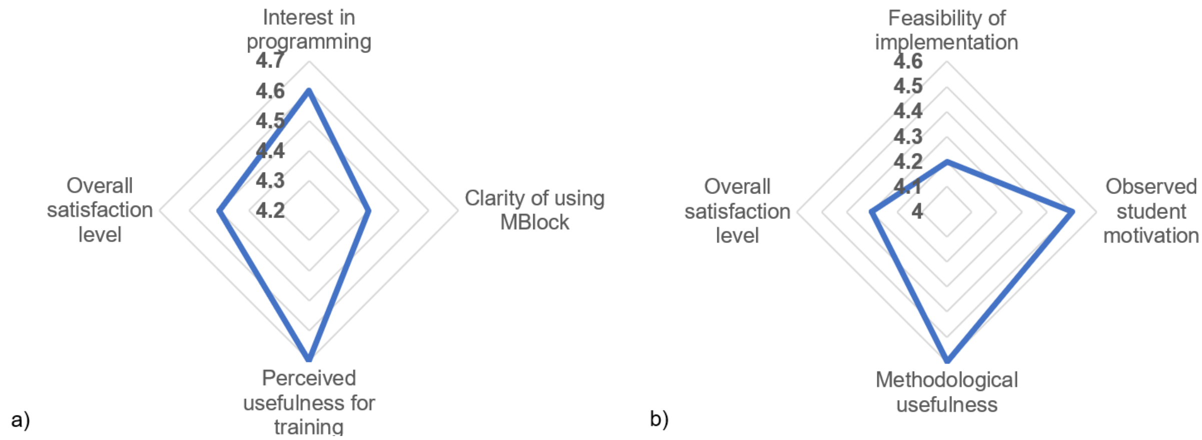
Figure 8

Perception Survey Averages Using the Likert Scale, a) students, b) teachers



DISCUSSION

The findings of this study demonstrate that integrating the STEAM methodology with the MBlock platform significantly supports the development of technological competencies and boosts student interest in science and technology, especially in contexts with limited access to educational resources. This combined approach proved to be both adaptable and impactful, providing students in vulnerable settings with meaningful, hands-on learning experiences.

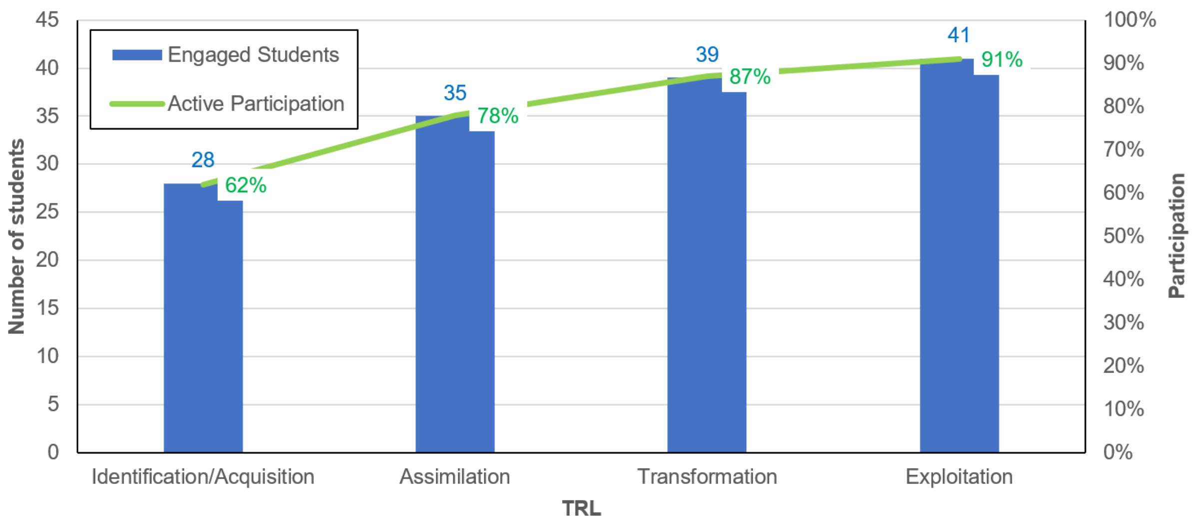
These results resonate with previous works, such as Fernández et al. (2021), who observed that the implementation of educational robotics within STEAM frameworks led to greater motivation and engagement in STEM areas. Similarly, Ferrada and Trujillo (2024) pointed out that digital tools like MBlock are effective for introducing programming and robotics concepts, while also enhancing students' problem-solving abilities and computational thinking.

Moreover, as Fonseca et al. (2021) emphasized that STEAM education is important in bridging the digital divide by offering equitable access to technological learning opportunities, particularly for students who might not encounter such tools outside of school. In this project, the MBlock-based intervention allowed students, regardless of their prior exposure to technology, to progressively build practical skills relevant to today's demands.

Figure 9 highlights the increase in student participation across the four stages of the project. Initial engagement during the Identification and Acquisition phase was moderate, with 58 % of students actively involved. However, as the methodology matured and the tool was more deeply integrated into the learning process, participation steadily climbed, reaching 91 % by the Exploitation phase. This upward trend reflects growing student confidence, enthusiasm, and autonomy in working with MBlock. It also underscores the effectiveness of a progressive, skill-building approach in fostering long-term engagement with STEAM subjects

Figure 9

Evolution of Student Participation



What sets this work apart is its structured, phased implementation, guided by levels of technological readiness. Rather than a one-time intervention, the process advanced from initial familiarization workshops to full curricular integration. Each phase was informed by ongoing assessment and feedback, allowing the project to grow in complexity and scope while maintaining its effectiveness. This approach ensured sustained student participation with an interdisciplinary learning, offering a model that can be replicated in similar educational environments seeking inclusive and innovative strategies.

CONCLUSIONS

This study demonstrates that integrating the MBlock platform within a STEAM-oriented educational model significantly enhances students’ ability to absorb and apply knowledge in programming and robotics, particularly in underserved educational environments. The implementation across the four stages: Identification and Acquisition, Assimilation, Transformation, and Exploitation, allowed for a progressive and structured development of students' technical and cognitive skills.

Quantitative findings revealed a notable improvement in academic performance, rising from an average of 6.8 to 9.1, accompanied by a steady increase in student engagement and participation, which grew from 58 to 91 % throughout the intervention. Furthermore, the high levels of satisfaction and perceived usefulness reported by both students and teachers, evidenced by Likert scale averages above 4, highlight the positive reception and educational value of the approach.

Beyond the technical achievements, the methodology fostered the development of key 21st-century skills, including creativity, critical thinking, and collaborative problem-solving. The gradual implementation strategy, aligned with levels of technological readiness, enabled students to move from basic familiarity with MBlock to fully integrating it into their curriculum through meaningful, hands-on learning experiences.

Overall, this initiative offers a viable and impactful model for promoting equitable access to technological education. It bridges gaps in digital literacy by equipping students with practical tools to face the demands of a technology-driven world. Future efforts should focus on expanding the implementation of this model to other educational contexts and conducting long-term assessments to understand its lasting effects further.

Conflict of Interest Statement

The authors declare that they have no conflicts of interest related to this research.

Authorship Contribution Statement

Angel Isaac Simbaña Gallardo: Conceptualization; Methodology; Writing – Original Draft; Writing – Review and Editing.

Mercedes Elizabeth Vargas Moreno: Conceptualization; Methodology; Writing – Original Draft; Writing – Review and Editing.

Fabricio Manuel Tipantocta Pillajo: Investigation; Writing – Original Draft; Writing – Review and Editing.

Gabriela Fernanda Yépez Posso: Data Curation; Writing – Original Draft; Writing – Review and Editing.

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