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HUMANIZAÇÃO DA MATEMÁTICA NO ENSINO SECUNDÁRIO: O IMPACTO DO JOGO NA CONTEXTUALIZAÇÃO HISTÓRICA E COGNITIVA

HUMANIZING MATHEMATICS IN SECONDARY EDUCATION: THE IMPACT OF GAME-BASED LEARNING ON HISTORICAL AND COGNITIVE CONTEXTUALIZATION

HUMANIZACIÓN DAS MATEMÁTICAS EN LA EDUCACIÓN SECUNDARIA: EL IMPACTO DEL JUEGO EN LA CONTEXTUALIZACIÓN HISTÓRICA Y COGNITIVA

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RESUMO

Introdução: O ensino tradicional da matemática apresenta, frequentemente, conteúdos como verdades abstratas e a-históricas, descontextualizadas da sociedade. Esta abordagem gera dificuldades de aprendizagem e uma perceção de que o conhecimento matemático não possui raízes humanas ou evolução cultural.
Objetivo: Utilizando uma abordagem de métodos mistos, este estudo pretende analisar o impacto do jogo educativo "Quem é Quem na Matemática?" na promoção da consciência histórica e da retenção conceptual entre os alunos do ensino secundário.
Métodos: Realizou-se uma intervenção pedagógica com 26 alunos, utilizando uma metodologia colaborativa de "galeria matemática". Os estudantes associaram contributos científicos a 20 matemáticos através de cartões informativos, focando-se na evolução de conceitos como os Números Complexos.
Resultados: A análise qualitativa e quantitativa revelou elevados níveis de motivação (4.9/5) e participação ativa (4.8/5). Os resultados indicam que a humanização das figuras históricas ajudou a mitigar a abstração de temas complexos, facilitando a argumentação baseada em evidências.
Conclusão: A integração dos jogos e da história da matemática parece ser uma estratégia eficaz para desmistificar a disciplina, transformando a sala de aula num espaço de investigação onde a lógica se liga ao legado humano.

Palavras-chave: história da matemática; jogos educativos; humanização do ensino; aprendizagem colaborativa; ensino secundário

ABSTRACT

Introduction: Traditional mathematics education often presents content as abstract, ahistorical truths, divorced from the context of society. This approach leads to learning difficulties and the perception that mathematical knowledge has no human roots or cultural evolution.
Objective: Using a mixed-methods approach, this study aims to analyze the impact of the educational game "Who's Who in Mathematics?" in promoting historical awareness and conceptual retention among secondary school students.
Methods: A pedagogical intervention was conducted with 26 students using a collaborative "mathematical gallery" methodology. Students matched scientific contributions to 20 mathematicians using information cards, focusing on the evolution of concepts such as Complex Numbers.
Results: Qualitative and quantitative analysis revealed high levels of motivation (4.9/5) and active participation (4.8/5). Results indicate that humanizing historical figures helped mitigate the abstraction of complex topics, facilitating evidence-based argumentation.
Conclusion: The integration of games and the history of mathematics appears to be an effective strategy for demystifying the discipline, transforming the classroom into a research space where logic connects to human legacy.

Keywords: history of mathematics; educational games; humanizing education; collaborative learning; secondary education

RESUMEN

Introducción: La enseñanza tradicional de las matemáticas suele presentar los contenidos como verdades abstractas y ahistóricas, descontextualizadas de la sociedad. Este enfoque genera dificultades de aprendizaje y la percepción de que el conocimiento matemático carece de raíces humanas o de evolución cultural.
Objetivo: Este estudio, que utiliza un enfoque de métodos mixtos, tiene como objetivo analizar el impacto del juego educativo "¿Quién es quién en matemáticas?" en la promoción de la conciencia histórica y la retención conceptual entre los estudiantes de secundaria.
Métodos: Se realizó una intervención pedagógica con 26 alumnos utilizando una metodología colaborativa de "galería matemática". Los estudiantes asociaron contribuciones científicas a 20 matemáticos mediante tarjetas informativas, centrándose en la evolución de conceptos como los números complejos.
Resultados: El análisis cualitativo y cuantitativo reveló altos niveles de motivación (4.9/5) y participación activa (4.8/5). Los resultados indican que la humanización de las figuras históricas ayudó a mitigar la abstracción de temas complejos, facilitando la argumentación basada en evidencias.
Conclusión: La integración del juego y la historia de las matemáticas parece ser una estrategia eficaz para desmitificar la disciplina, transformando el aula en un espacio de investigación donde la lógica se conecta con el legado humano.

Palabras clave: historia de las matemáticas; juegos educativos; humanización de la enseñanza; aprendizaje colaborativo; educación secundaria

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INTRODUCTION

In the contemporary educational landscape, Mathematics is frequently perceived as a static, abstract body of knowledge, often decontextualized from its human and social roots. This ahistorical perspective contributes to a significant gap between discipline and society, leading students to view mathematical concepts as decontextualized abstractions that exist independently of human effort or cultural evolution. Research indicates that Mathematics has undergone profound changes over time, shaped by shifting views of what the discipline represents and how it should be taught (Chorlay et al., 2022; Fauvel & Van Maanen, 2000; Jankvist, 2009; Radford, 2014). Addressing these challenges requires a paradigm shift towards the humanization of mathematics, where the integration of the History of Mathematics (HM) acts not as a biographical ornament, but as a fundamental epistemological tool to reveal discipline as a living cultural product.

As pointed out by Maria Fernanda Estrada, the study of biographies of mathematicians transforms the mathematicians into “live people” and presenting them with their successes and failures shows them as humans like all the others. She argues that through biographies we can introduce the “dynamics that come from the evolution of ideas, of their genesis and successive approximations till the final form that frequently shows up with different people in different places” (Estrada, 1993).

This study argues for a socio-mathematical approach, emphasizing that mathematical concepts are the result of human necessity, rivalries, and philosophical debates. For secondary school students, identifying with the personalities and cultural backgrounds of mathematicians fosters a sense of curiosity that abstract formulas alone cannot provide. This is particularly evident when teaching complex topics such as Complex Numbers. For many students, the introduction of the imaginary unit *i* feels like an arbitrary imposition. However, when the 16th-century disputes between Girolamo Cardano and Niccolò Tartaglia are revealed, the concept gains a human dimension. Understanding that "imaginary" numbers were initially met with skepticism by the mathematical community allows students to validate their own cognitive difficulties and engage in deeper argumentation (Alves, 2020).

The Portuguese Mathematician José Sebastião e Silva (1914-1972) used a lot of history of mathematics in his mathematics textbooks, including the history of Complex Numbers with the works of Cardano, Tartaglia‘s formula, the “wild quantities” of Bombelli, and the problem of constructing a new structure that would be able to include all solutions to polynomial equations (Carvalho e Silva, 1993).

To operationalize this humanization, the educational game “Who’s Who in Mathematics?” was developed as a structured pedagogical tool. As Miguel de Guzmán (1994) pointed out, games and mathematics share a common nature in their practice; therefore, the use of Game-Based Learning (GBL) should be considered a serious instrument for fostering historical awareness and conceptual retention.

Games are powerful in their own right and have been used in a number of different contexts in the teaching of mathematics, like GBMM-Game Based Mathematical Modeling in order to “effectively engage students” (Roth, 2025). It has been used combining ICT tools, as in the work of the project “Magia dos Números” (Number´s magic) whose goal was to foster the encouraging a positive attitude toward mathematics (Martins et al., 2002).

By transforming the classroom into a "mathematical gallery," students are challenged to bridge the gap between logic and legacy. Building upon previous research regarding the effectiveness of GBL (Akintewe & Ikechukwu, 2025; Caridade & Pereira, 2023; Morais et al., 2024), this paper seeks to answer the following research questions:

- **RQ1:** How does the "Who’s Who in Mathematics?" game contribute to demystifying mathematics as a body of knowledge isolated from society?
- **RQ2:** How does the introduction of historical and biographical contexts influence student motivation and their perception of mathematical discovery as a human process?

By intertwining the development of concepts like Complex Numbers with the lives of those who shaped them, from René Descartes to Leonhard Euler, this methodology argues that a holistic understanding of mathematics is only possible when we reconnect the science to the society that produced it.

1. THEORETICAL FRAMEWORK

The integration of history and games in mathematics education is supported by a robust body of literature that emphasizes the social and human dimensions of science as a counter-narrative to traditional, ahistorical teaching methods (D’Ambrosio, 1985; Valero, 2004; Dorce, 2025). This study is built upon the premise that teaching mathematics through its history is not merely about reciting dates or serves as a powerful epistemological tool to help students navigate the intellectual obstacles inherent in mathematical concepts. As noted by Chorlay et al. (2022), understanding that mathematics has undergone significant shifts in perspective is essential for deep learning. By exploring the genesis of ideas (such as the transition from the geometric resolution of equations to symbolic algebra), students can mirror the mental processes of great mathematicians, transforming what were once perceived as decontextualized abstractions into meaningful historical milestones (Heeffer, 2006; Clark et al., 2022).

This perspective is crucial in addressing the "dehumanization" of mathematics, where formulas are often presented as *a priori* truths devoid of human agency (Ernest, 2018). Struik, author of *A Concise History of Mathematics*, argues that incorporating the

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history of mathematics into classroom practice is essential, as it satisfies the natural curiosity about how mathematical ideas originated and developed, fosters an appreciation of our cultural heritage, and enriches teaching through historical episodes and anecdotes that render the subject more human and engaging (Struik, Recent research into humanistic mathematics suggests that introducing narrative elements into the curriculum allows students to perceive mathematics as a living, socio-cultural product (Alves, 2020; Kurianski et al., 2022). When students learn, for instance, about the 16th-century disputes between Cardano and Tartaglia, the "imaginary" nature of Complex Numbers ceases to be a logical imposition and becomes a human solution to a crisis of knowledge (Grosholz, 2013). This connection significantly reduces mathematical anxiety by showing that even the most brilliant minds faced uncertainty and rejection before reaching consensus. Furthermore, identifying with the historical struggles of these figures promotes a more inclusive environment, where the discipline is seen as a collective intellectual journey rather than a solitary, elitist pursuit. In this sense, the history of mathematics acts as a catalyst for student agency, allowing learners to see themselves as potential contributors to a field that is constantly evolving rather than a finished, unchangeable doctrine (Chorlay et al., 2022).

Educational games serve as the necessary catalyst to operationalize this humanization within the classroom. According to Guzmán (1994), the playfulness inherent in games mimics the heuristic nature of mathematical discovery, providing a safe environment for trial and error (Cès et al., 2025). In a game-based learning (GBL) environment, the classroom is transformed into a "mathematical gallery" where students act as active investigators rather than spectators. Current trends in GBL research emphasize that interactive and collaborative environments are essential for developing 21st-century skills and enhancing students' interest and self-efficacy through historical empathy (Morais et al., 2024; Marín & Cantillo, 2025; Arthur et al., 2026). This shift towards active learning strategies is consistent with contemporary pedagogical practices that prioritize student-centered environments as a means to foster deeper engagement and knowledge construction (Mangas, 2020; Bhardwaj et al., 2025). Previous studies have demonstrated that such methodologies enhance not only conceptual retention but also transversal skills such as collaboration, critical thinking, and evidence-based argumentation (Caridade & Pereira, 2023). By employing the “Who’s Who in Mathematics?” game, this research bridges the gap between science and society, ensuring that logic is inextricably linked to the intellectual legacy of the people who shaped it.

2. METHODS

Employing a mixed-methods design, this study gathered data through student perception surveys and classroom observation notes, which were analyzed via descriptive statistics and thematic content. The study was conducted with a convenience sample of 26 secondary school students (11th and 12th grades) in a public school in Portugal. These students were engaged in the study of Complex Numbers, a topic frequently associated with high levels of abstraction. Complementing this sample, two mathematics teachers participated as observers and evaluators, providing expert feedback on the pedagogical efficiency of the intervention.

The intervention was centered on the educational game “Who’s Who in Mathematics?”, which was specifically designed to bridge the gap between abstract concepts and their historical origins. The materials were curated to align with the secondary curriculum, focusing on the evolution of algebraic thought (Heeffer, 2006). The game environment was structured as a "mathematical gallery," consisting of 20 high-quality, laminated portraits of mathematicians displayed in plastic frames throughout the classroom. To facilitate the activity, a set of 50 information cards was developed, detailing specific scientific contributions or cultural curiosities. The physical design, visual layout, and the format of these historical clues are showcased in Figure 1.



Figure 1 – Sample information cards detailing mathematical contributions and historical curiosities

To illustrate the cognitive depth and the connection between history and complex numbers, Table 1 presents a selection of information cards used during the activity. The cards were designed to connect pioneers like Rafael Bombelli, Leonhard Euler, and Carl Friedrich Gauss to their respective breakthroughs, such as the introduction of the imaginary unit i or the Fundamental Theorem of Algebra. Furthermore, the inclusion of renowned Portuguese figures, such as Sebastião e Silva, aimed to contextualize the discipline within the students' own national scientific history, fostering identity and engagement.

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Table 1 – Examples of Information Cards: Connecting History and Complex Numbers

Mathematician	Information Card / Challenge
Rafael Bombelli (1526–1572)	An Italian hydraulic engineer who introduced the first operational rules for complex numbers. He used expressions like *"più di meno"* to represent the square root of negative numbers.
Leonhard Euler (1707–1783)	The Swiss mathematician responsible for introducing the notation *i* for the imaginary unit and the formula $e^{i\theta}=cos\theta+isin\theta$, essential for the trigonometric form.
Carl Friedrich Gauss (1777–1855)	Known as the "Prince of Mathematics", he provided the first rigorous proof of the Fundamental Theorem of Algebra, ensuring the full acceptance of complex numbers.
Sebastião e Silva (1914–1972)	A 20th-century Portuguese mathematician and educator who used the equation x^2=-9 in his textbooks to introduce students to complex numbers.

The pedagogical implementation followed a structured five-stage process: introduction, preparation, development (20 minutes), collective scoring (20 minutes), and a final synthesis. During the developmental phase, the classroom was reorganized into a 'mathematical gallery,' an immersive environment that encouraged students to circulate between tables to examine the framed portraits and debate the historical clues (Figure 2). To facilitate organization and progress tracking, students were organized into collaborative groups, each assigned a kit identified by specific color-coded stickers. The primary task required these groups to establish logical connections between their information cards and the mathematicians on display. To ensure intellectual rigor, the game's complexity was intentionally calibrated by including 'distractor' mathematicians with no assigned cards, as well as figures associated with multiple contributions. This strategic design choice was fundamental to mitigate superficial conjecture, compelling students to engage in substantive collaborative dialogue and rigorous, evidence-based justification of their scientific associations.



Figure 2 – Classroom implementation: students collaborating in groups and exploring the "mathematical gallery" to match information cards.

Throughout the session, the teacher's role transitioned from a traditional instructor to a mediator, circulating among the groups to prompt reasoning and ensure that the focus remained on the historical and human context of science. The impact of this methodology was documented through the final verification phase, where teachers and students discussed the correct associations (Figure 3). Data were collected through 5-point Likert scale self-assessment forms and teacher evaluation reports, focusing on dimensions such as motivation, active participation, and the perceived utility of the History of Mathematics. The statistical analysis involved calculating arithmetic means to determine the intervention's success in fostering critical thinking and historical empathy (Arthur et al., 2026).

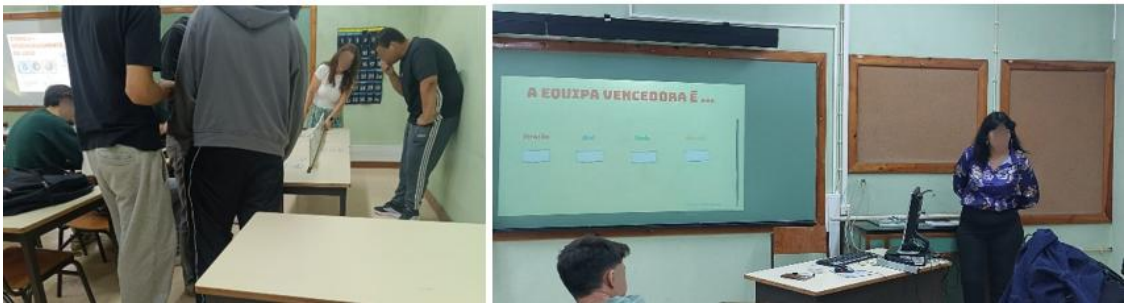


Figure 3 – Final verification phase: teachers and students discussing correct associations and historical context

3. RESULTS

The pedagogical intervention yielded highly positive results, as evidenced by the convergence of quantitative data from student self-assessments and qualitative feedback from the participating teachers. The data indicates that the "Who's Who in Mathematics?" game successfully transformed the classroom into a space of high cognitive and emotional engagement.

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3.1 Quantitative Analysis

The quantitative impact was measured through a 5-point Likert scale questionnaire completed by the students ($n = 26$). As detailed in Table 2, the average scores were exceptionally high, with all indicators exceeding 4.5. Notably, "Motivation to participate" and "Learning new historical or mathematical contexts" reached an average of 4.9, suggesting a near-unanimous positive reception of the methodology. These metrics align with the theoretical premise that integrating historical narratives significantly enhances students' intrinsic interest and academic self-efficacy (Arthur et al., 2026).

Table 2 – Average Scores from Student Self-Assessment ($n = 26$)

Assessment Indicator	Average Score (1-5)
Active participation in group discussions	4.8
Understanding the history behind mathematical content	4.7
Learning new historical or mathematical contexts	4.9
Motivation to participate in the game	4.9
Contribution to consolidating mathematical content	4.6

3.2 Qualitative Findings and Teacher Evaluation

Qualitatively, students reported that the "human side" of the mathematicians acted as a bridge to overcome the perceived abstraction of Complex Numbers. Two primary cognitive strategies were identified during the observation of the groups: chronological deduction (matching dates on portraits with historical periods) and keyword identification (e.g., associating the "imaginary unit" with Euler or "cubic equations" with Cardano).

The evaluation from the participating teachers ($n = 2$) corroborated these findings. The activity received a perfect score (5/5) regarding its ability to stimulate critical thinking and argumentation. The teachers highlighted the game's efficiency as a diagnostic tool, observing that while students were quick to identify 18th-century figures, earlier mathematicians like Rafael Bombelli (16th century) triggered more intensive debate and required deeper analytical effort. Furthermore, the teachers emphasized that the inclusion of Portuguese figures, such as Sebastião e Silva, was a crucial element in fostering a national scientific identity among the students.

4. DISCUSSION

The high scores obtained across all assessment indicators (averaging above 4.5/5.0) corroborate the initial hypothesis that the humanization of mathematics, operationalized through GBL, acts as a powerful catalyst for student engagement. The discussion focuses on three main pillars: historical empathy as a cognitive bridge, the role of national identity, and the pedagogical implications for future implementations.

4.1 Historical Empathy and Conceptual Abstraction

The results indicate that the "human side" of mathematicians meaningfully contributed to mitigating the perceived abstraction of Complex Numbers. By engaging with the historical struggles and rivalries (such as the Cardano-Tartaglia dispute), students developed what can be termed as historical empathy. This finding aligns with Sriraman (2024), suggesting that when mathematics is presented as a narrative of human endeavor rather than a static set of rules, student agency and self-efficacy are substantially enhanced. The reported use of "chronological deduction" and "keyword identification" by the most successful groups shows that the history of mathematics is not just a decorative element, but a functional heuristic tool that aids in the organization of mathematical knowledge (Chorlay et al., 2022).

4.2 Socio-cultural Context and Scientific Identity

A distinctive finding of this study was the impact of including Portuguese figures like Sebastião e Silva or Anastácio da Cunha. The teacher evaluations highlighted this as essential for fostering a national scientific identity. This suggests that the "humanization" of mathematics is most effective when it is culturally situated. By bridging the gap between global mathematical history and local intellectual legacy, the intervention moved beyond mere content delivery to a form of cultural empowerment, an aspect increasingly valued in contemporary humanistic mathematics (Alves, 2020; Bhardwaj et al., 2025).

4.3 Pedagogical Reflection and Limitations

Despite the overall success, the transition of the teacher's role to a mediator revealed important logistical and pedagogical nuances. The identified need for a "more stable mounting system" for the portraits and the occasional imbalance in group participation point to the inherent challenges of managing active learning laboratories. These findings resonate with Morais et al. (2024), who argue that GBL requires not only careful material design but also a refined strategy for managing group dynamics to ensure balanced participation.

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Furthermore, the teacher-led suggestion to include "distractor" cards in future iterations reflects a sophisticated pedagogical insight: the move from simple matching to critical discrimination**.** This adjustment would elevate the game from a diagnostic tool to a high-level cognitive challenge, compelling students to use exclusionary logic, a fundamental skill in mathematical reasoning. Lastly, while the 60-minute duration was sufficient for the core task, the demand for more time for the final synthesis suggests that the "collective discussion" phase (Figure 3) is perhaps the most vital part of the intervention, where informal game-based discoveries are transformed into formal mathematical understanding.

CONCLUSION

The present study demonstrates that the "dehumanization" of mathematics can be effectively countered through a synergistic approach involving the History of Mathematics and GBL. By addressing the core research questions, this study concludes that the integration of historical narratives acts as a significant catalyst for student engagement. Specifically, the findings reveal that providing a human context to scientific discoveries transforms the perception of mathematics from a static set of rules into a living, socio-cultural product.

Regarding the impact on learning abstract concepts, the "Who's Who in Mathematics?" game appears to be an effective epistemological bridge. The intervention allowed students to transition from viewing Complex Numbers as arbitrary impositions to recognizing them as human solutions to historical intellectual crises. The high levels of student motivation (4.9/5.0) and the teachers' validation of the game as both a diagnostic and critical thinking tool suggest that this methodology is highly viable for secondary education. Furthermore, the inclusion of local scientific figures, such as Sebastião e Silva, emerged as a key factor in building students' scientific identity, proving that mathematical literacy is most impactful when it is culturally and historically situated.

While the core pedagogical objectives were fully met, the study identified specific logistical and pedagogical nuances that warrant attention. The transition of the teacher's role to a mediator and the management of collaborative group dynamics are essential factors for the success of such active learning laboratories. In conclusion, humanizing the curriculum is not an alternative to academic rigor, but rather a prerequisite for meaningful and inclusive mathematical education (Vale & Barbosa, 2025).

For future research, it is recommended to expand this methodology to other high-abstraction topics within the secondary and higher education curricula, such as Calculus, Linear Algebra, or Non-Euclidean Geometry. Further longitudinal studies could evaluate the long-term impact of historical empathy on students' academic performance and their choice of STEM careers. Additionally, developing a digital version of the "Mathematical Gallery" could mitigate the logistical challenges identified regarding physical materials, allowing for a broader implementation in diverse educational settings and fostering a more stable environment for critical discrimination and collaborative problem-solving. Furthermore, as a limitation of this qualitative approach, the study lacked a control group to directly compare performance outcomes with and without the intervention; thus, future research should incorporate comparative pre- and post-test assessments to rigorously measure the exact cognitive gains in Complex Numbers.

AUTHORS' CONTRIBUTION

Conceptualization, C.C., M.A. and V.P.; data curation, C.C. and M.A.; formal analysis, C.C. and M.A.; investigation, C.C., M.A., V.P., J.S. and A.P.A.; methodology, C.C., M.A. and V.P.; project administration, C.C. and M.A.; resources, C.C. and V.P.; supervision, C.C. and M.A.; validation, C.C., J.S. and A.P.A.; visualization, C.C., M.A. and V.P.; writing – original draft, C.C.; writing – review & editing, V.P., J.S. and A.P.A.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.

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