GAMIFICATION APPLIED TO THE TEACHING OF FIRST-DEGREE EQUATIONS USING A VIRTUAL TORQUE BALANCE

GAMIFICAÇÃO APLICADA AO ENSINO DE EQUAÇÕES DO 1º GRAU UTILIZANDO UMA BALANÇA DE TORQUE VIRTUAL

GAMIFICACIÓN APLICADA A LA ENSEÑANZA DE ECUACIONES DE PRIMER GRADO UTILIZANDO UNA BALANZA DE TORQUE VIRTUAL

10.56238/edimpacto2025.026-001

Leonardo Lois Rodrigues[1], Sérgio de Oliveira[2], Eduardo Sarquis Soares[3], Rone Ilídio da Silva[4] and Reinaldo Silva Fortes[5]

ABSTRACT

Solving first-degree equations presents recurring challenges for elementary school students, especially in understanding concepts such as equality, negative numbers, and the first steps in studying algebra. In addition, children and adolescents have been significantly impacted by the introduction of digital technologies, with little-known consequences. In this context, dynamic and interactive methodologies based on digital games present themselves as alternatives to conventional teaching. This article addresses the application of gamification as an active methodology in teaching first-degree equations, using an application that simulates a scale whose balance depends on the torque of the weights placed on its rod. The central question of this research is about the impact of using these methodologies in the educational environment and, in particular, the potential of gamification as an innovative strategy for teaching mathematics. The research was conducted with 33 seventh-grade students, using the application in game modes, which presents progressive challenges, social competition, and feedback on the participants' performance. Gamification was adopted based on the premise that it attracts the attention of students in this age group, promoting engagement and motivation for learning. At the end, the students' perception was evaluated qualitatively using the Likert scale.

[1]Federal University of São João Del Rey, Alto Paraopeba campus
ORCID: 0009-0004-3719-1936
E-mail: leoloisprofmat2022@gmail.com
[2]Federal University of São João Del Rey, Alto Paraopeba campus
ORCID: 0000-0002-8351-8889
Email: sergiool@ufsj.edu.br
[3]Federal University of São João Del Rey, Alto Paraopeba campus
ORCID: 0000-0003-4651-3840
E-mail: esarquis@ufsj.edu.br
[4]Federal University of São João Del Rey - MG, Alto Paraopeba campus
ORCID: 0000-0002-5221-4161
E-mail: leoloisprofmat2022@gmail.com
[5]Federal University of Ouro Preto - MG
ORCID: 0000-0002-2032-3291
E-mail: reifortes@ufop.edu.br

Keywords: Gamification. First-degree equations. Balance scale. Negative numbers. Mathematics teaching. Active methodologies.

RESUMO
A resolução de equações do 1º grau apresenta desafios recorrentes para alunos do ensino fundamental, especialmente na compreensão de conceitos como igualdade, números negativos e os primeiros passos no estudo da álgebra. Além disso, crianças e adolescentes vêm sofrendo impactos significativos com a introdução de tecnologias digitais, com consequências pouco conhecidas. Nesse contexto, metodologias dinâmicas e interativas baseadas em jogos digitais apresentam-se como alternativas ao ensino convencional. Este artigo aborda a aplicação da gamificação como metodologia ativa no ensino de equações do 1º grau, utilizando um aplicativo que simula uma balança cujo equilíbrio depende do torque dos pesos colocados em sua haste. A questão central desta pesquisa é sobre o impacto do uso dessas metodologias no ambiente educacional e, em particular, o potencial da gamificação como estratégia inovadora para o ensino da matemática. A pesquisa foi conduzida com 33 alunos do 7º ano do ensino fundamental, utilizando o aplicativo em modos de jogo, o qual apresenta desafios progressivos, competição social e feedback sobre o desempenho dos participantes. A gamificação foi adotada a partir da premissa de que ela atrai a atenção dos alunos nessa faixa etária, favorecendo o engajamento e a motivação para o aprendizado. Ao final, a percepção dos alunos foi avaliada de forma qualitativa usando a escala Likert.

Palavras-chave: Gamificação. Equações do 1º grau. Balança de equilíbrio. Números negativos. Ensino de matemática. Metodologias ativas.

RESUMEN
La resolución de ecuaciones de primer grado presenta retos recurrentes para los alumnos de primaria, especialmente en la comprensión de conceptos como la igualdad, los números negativos y los primeros pasos en el estudio del álgebra. Además, los niños y adolescentes están sufriendo un impacto significativo con la introducción de las tecnologías digitales, cuyas consecuencias son poco conocidas. En este contexto, las metodologías dinámicas e interactivas basadas en juegos digitales se presentan como alternativas a la enseñanza convencional. Este artículo aborda la aplicación de la gamificación como metodología activa en la enseñanza de ecuaciones de primer grado, utilizando una aplicación que simula una balanza cuyo equilibrio depende del torque de los pesos colocados en su brazo. La cuestión central de esta investigación es el impacto del uso de estas metodologías en el entorno educativo y, en particular, el potencial de la gamificación como estrategia innovadora para la enseñanza de las matemáticas. La investigación se llevó a cabo con 33 alumnos de 7.º curso de la enseñanza primaria, utilizando la aplicación en modos de juego, que presenta retos progresivos, competición social y comentarios sobre el rendimiento de los participantes. La gamificación se adoptó partiendo de la premisa de que atrae la atención de los alumnos de esta edad, favoreciendo el compromiso y la motivación para el aprendizaje. Al final, se evaluó la percepción de los alumnos de forma cualitativa utilizando la escala Likert.

Palabras clave: Gamificación. Ecuaciones de primer grado. Balanza de equilibrio. Números negativos. Enseñanza de las matemáticas. Metodologías activas.

INTRODUCTION

School learning aligned with the individual's reality intensifies the possibilities for the topics addressed to make sense in their daily lives. Considering that this reality is strongly influenced by the technological transformations of the last decades, it is essential to evaluate what such technologies cause as changes in the educational environment. Among these technologies, digital games emerge as powerful resources, as they combine playfulness and technology, promoting more motivating and engaging environments. In line with this approach, Vianna et al. (2013) highlight that games are an effective technological tool, when, in a playful way, they provide motivation and, therefore, engagement. Although the authors deal with games in a broader context, it is possible to apply their argument to the school environment, since motivation and engagement are essential elements for learning. Considering this approach, in the educational context, benefits could be perceived in concentration, task accomplishment, dedication and analysis of challenges, in a playful environment.

This perspective dialogues directly with active methodologies, which value the student's protagonism and, for decades, have been pointed out as an alternative to the traditional teaching model centered on the transmission of content. D'Ambrosio (1989) criticizes the excessive emphasis on the amount of content to the detriment of meaningful learning, warning that this model can limit students' creativity and critical sense. According to D'Ambrosio, a more dynamic and investigative teaching, in which the teacher assumes the role of mediator and stimulates the active construction of knowledge, favors deeper and more engaged learning. Along the same lines, Prikladnicki et al. (2009) point out that the adoption of traditional approaches in teaching can lead to a demotivating and inefficient process. Methods that encourage greater student participation, on the other hand, contribute to a more engaging and transformative teaching, promoting the active construction of knowledge.

In this scenario of valuing active participation, recent studies indicate that the insertion of digital games and practical challenges in the teaching of mathematical and computational concepts can promote greater commitment and understanding of students. Dias & Araújo (2024) highlight that the use of active methodologies in the construction of parallel computational thinking has shown positive results by encouraging student participation and facilitating the assimilation of complex content. According to the authors, parallel computational thinking involves the development of cognitive skills related to the execution of multiple actions simultaneously and in a coordinated manner, in addition to solving problems composed of different parts that must be solved in parallel. Approaches like this demonstrate that, when well structured, interactive technologies can contribute significantly to learning.

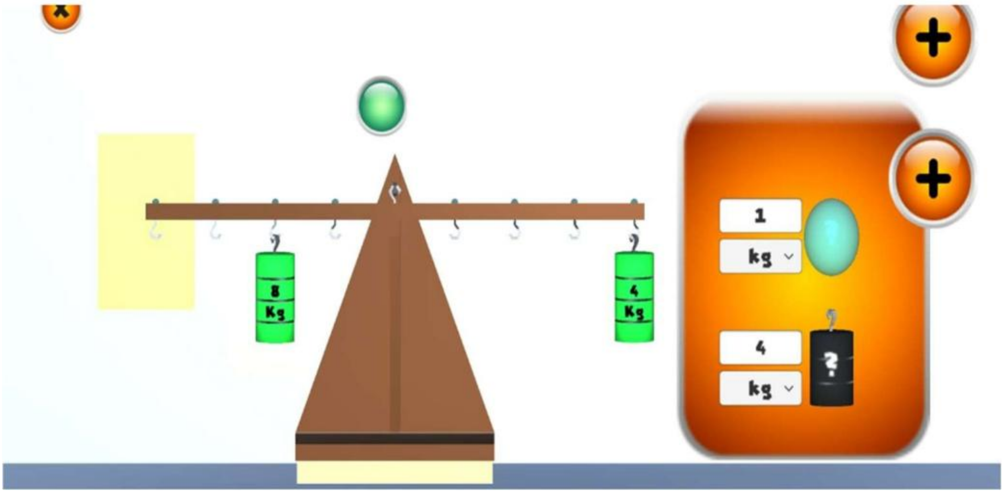
Among these interactive technologies, gamification stands out as one of the active methodologies, with the potential to engage students in specific disciplines. In this sense, Altino Filho et al. (2020), Brazilian research points out that active methodologies, such as problem-based learning, the flipped classroom, and gamification, favor more dynamic and participatory teaching, promoting student protagonism and making learning more relevant. They also add that, in mathematics teaching, these approaches encourage critical thinking and problem-solving, despite the challenges related to teacher training and curricular adaptation.

Hypothetically, we propose that digital technologies can adapt to active methodologies when produced appropriately. In this context, the use of these technologies can be aligned with active methodologies to enhance learning. This idea motivated the experiment proposed in the research described here.

Thus, considering the potential of active methodologies to make teaching more dynamic and meaningful, it is relevant to investigate their application in the teaching of mathematical concepts. In particular, teaching 1st degree equations still represents a substantial challenge for many elementary school students, especially due to the traditional approach based on memorizing algebraic rules and procedures. Many students show difficulties in understanding mathematical equality and in the symbolic manipulation of algebraic expressions, which can compromise their future performance in more advanced content. Therefore, it is essential to investigate more effective and engaging methodologies that help in the development of algebraic thinking, promoting more consistent and interactive learning. This study seeks to explore the use of the virtual torque scale and gamification as pedagogical strategies to facilitate the resolution of equations of the 1st degree, making the process more dynamic and accessible for students.

In the virtual torque balance, the principle of torque balance is observed. The scale remains in balance even with different weights in different positions, due to the relationship between force, distance, and torque. The torque, calculated by the product of the force applied by the weight and the distance to the fulcrum (or axis of rotation), compensates for the differences in the values of the weights. Figure 1 shows the torque scale used in the work in equilibrium situation. Despite the different weights, the different distances to the center of support compensate for the balance, a situation that can be used to represent coefficients of linear equations. This tool not only realizes abstract mathematical concepts, but also aligns with contemporary demands for active and technological methodologies in education.

Figure 1: Representation of the Virtual Torque Balance developed by the authors.



In addition to the pedagogical foundations, this approach is supported by the Law of Guidelines and Bases (LDB[6]), which highlights the importance of adapting education to the demands of contemporary society, encouraging the integration of digital skills, such as programming, robotics, and computing in the curriculum of elementary and secondary education. This direction strengthens the inclusion of technological tools in the school environment, promoting innovations such as gamification and the use of interactive technologies in mathematics teaching.

Additionally, the National Common Curriculum Base (BNCC) reinforces this approach by emphasizing the use of technological processes and tools in the teaching of Mathematics. Among the topics highlighted, computational thinking stands out as an essential skill in the current educational context, related to the ability to formulate and solve problems logically, efficiently and with the support of digital technologies. In the preamble to the BNCC, computational thinking is pointed out as a skill to be developed through processes such as problem solving, investigation, and modeling — strategies considered fundamental for mathematical activity. These processes contribute both to mathematical literacy and to the development of computational thinking throughout Elementary School. Among the objectives of the BNCC, the encouragement of the use of digital technologies to model and solve everyday problems, of a social nature or other areas of knowledge, validating strategies and results, stands out. In addition, the BNCC descriptors — specific

[6]Available at: https://legislacao.presidencia.gov.br/atos/?tipo=LEI&numero=9394&ano=1996&ato=3f5o3Y61UMJpWT25a, accessed February 10, 2025

guidelines for the development of skills at each stage of basic education — also point in this direction. The descriptor EF07MA18, for example, directed to the 7th grade, encourages the resolution and elaboration of problems represented by polynomial equations of the 1st degree, using properties of equality. Similarly, the descriptor EF08MA09, aimed at the 8th grade, proposes the resolution of problems involving polynomial equations, with or without the use of technologies. Thus, these guidelines reinforce the importance of producing knowledge that explores the integration of digital technologies in teaching, considering the relevance and potential of these tools in the school context.

Based on this scenario, we consider games as technological tools, which propose that learning happens in a playful way. This is because motivation and active participation are essential elements for dedication and analysis of tasks in a gamified educational environment. According to Johnson et al (2014), gamified environments can contribute to the creation of motivational contexts based on exciting challenges, rewards for dedication and efficiency. As an example of the impact of this trend on current practices, they point to games and gamification as important digital strategies within educational technologies for the coming years.

In line with this, this work presents a proposal for an active methodology with gamification aimed at teaching equations of the 1st degree, inspired by the virtual torque scale model developed by Carvalho (2023), but with adaptations and improvements made to meet the objectives of this research. Among the changes made, the introduction of gamified stages, with the objective of increasing student engagement, and the expansion of the number of phases, promoting a gradual evolution in the complexity of the challenges proposed in the application, stand out. The use of the scale was fundamental for practical visualization in the teaching of 1st degree equations, allowing students to solve equations interactively, manipulating weights to balance the scale, with the mediation of the teacher throughout the process. This approach provided students with a more intuitive and visual experience. The application was developed using language. C#, within the Unity development environment[7]. This development environment allows applications to be generated for Windows, Linux, MacOS, Android, IOS operating systems, and also for running on the Web, ensuring portability both in the classroom and in remote environments.

It is important to highlight that the use of the torque balance for teaching equations is not unprecedented, as pointed out by studies such as those by Andrews & Sayers (2012),

[7] Available at: https://unity.com

Marinho (2022) and Stephens et al (2020). However, the contributions of this work, which differentiate it from other studies in the literature, are: (i) the differentiated presentation of the scale, in a graphic and intuitive way; (ii) the use of balloons to represent negative numbers; and, mainly, (iii) the use of the scale in a gamified scenario, with a competition held among students. This competition, representing gamification in the learning environment, was used to analyze its impact on student motivation and the application of the principle of balance of the scales in solving equations.

In addition to these technical contributions, this work was developed in the context of a project funded by a funding agency, which involves two universities, and whose objective is to encourage the development of computational thinking in elementary school teachers. The project has courses and partnerships, aiming at the development and application of computational solutions from these teachers. One of the authors of this work participated in one of the trainings and worked to apply the concepts in public schools. Thus, one of the contributions of this work consists of examining the result of the application of the concepts of computational thinking in public schools and verifying, to some extent, whether this insertion can bring results in the sense of improving the quality of basic education.

In this context, this study seeks to answer the following research question: How do gamification and the use of the virtual torque scale impact students' motivation and learning in the teaching of 1st degree equations? For this, the research is based on active methodologies and explores different approaches, already discussed in the literature, on the teaching of equations. In addition, the procedures adopted for the development and application of the experiment in the classroom are presented, as well as the analysis of the results obtained. Finally, the main contributions of this work and possibilities for future investigations are discussed. For better organization, the rest of this article is structured as follows: Section 2, Computational Thinking, Active Methodologies and Gamification; Section 3, Theoretical Frameworks and Related Works; Section 4, Methodology; Section 5, Results; and Section 6, Conclusions and Future Works.

COMPUTATIONAL THINKING, ACTIVE METHODOLOGIES AND GAMIFICATION

This section presents the main theoretical foundations of this work. Initially, the concept of computational thinking is addressed, highlighting its importance in the contemporary educational context. Then, active methodologies and their role in the transformation of pedagogical practices are discussed. Finally, gamification is explored as a didactic strategy that integrates the two previous axes, focusing on solving equations of the 1st degree. For better organization, the section is structured in the following subsections: 2.1 Computational Thinking; 2.2 Active Methodologies; 2.3 Gamification and beyond subsections 2.4 to 2.8, which deal with practical aspects of gamification, such as the target audience, learning objectives, proposal structure, and resources used.

COMPUTATIONAL THINKING

Improving the quality of basic education is essential for the country's development, especially in the face of the poor results achieved in international exams, such as PISA (Inep, 2023) and TIMSS. In this sense, the application of Informatics in basic education is a tool with proven successful results in several works (Coura et al., 2023). However, there is great difficulty in the application of these computational tools in the context of basic education, such as the lack of teacher training and the scarcity of solutions appropriate to the reality of schools, often due to the distance between computer specialists and educators who work in basic education.

The low insertion of computational thinking in the school curriculum is one of the factors that hinder this implementation. Although it is an essential skill for the twenty-first century, computational thinking is not yet part of the curricular structure of basic education in Brazil (França and Tedesco 2015), nor is it widely addressed in teaching degrees.

The present work is part of a project that seeks to act on this challenge through the training of basic education teachers, focusing on the development of computational thinking. The initiative involves the offer of courses, partnerships with schools and has as goals the development of educational software, teacher qualification for the use and creation of these tools, in addition to the production of academic works that report experiences and contribute to the advancement of the state of the art and to the integration of computational resources in the school context.

In this scenario, the development of computational thinking has been consolidated as a relevant goal in contemporary educational practices, especially in the field of Mathematics. It is a skill that involves the mobilization of strategies such as problem decomposition, pattern recognition, abstraction, and the creation of algorithms to solve tasks with the support of digital resources. The BNCC indicates that this type of reasoning can be promoted through investigative activities, problem solving and modeling processes, which play a central role in the teaching of Mathematics throughout Elementary School.

In this context, the present research presents a teaching proposal that seeks to favor the development of computational thinking through an interactive approach aimed at solving linear equations. The application was carried out with students from the 7th grade of Elementary School II, as will be detailed in the methodology section. The professor responsible for conducting the research was previously trained in the context of computational thinking, with the support of the project team, both in the planning and implementation of the activity in the classroom. It is expected that the result of this work can contribute with state of the art to the development of computational thinking in basic education, especially in gamification techniques. Considering that the BNCC provides, for the 7th grade, the development of algebraic thinking through modeling and problem solving with equations of the 1st degree, it is understood that proposals such as the one described here can contribute to this process, especially by integrating digital technologies and encouraging logical reasoning and the construction of solution strategies.

ACTIVE METHODOLOGIES

Active methodologies have been consolidating as a response to the educational transformations required by contemporary society, proposing alternatives to traditional models centered on the transmission of content. They assume as a premise that learning is a dynamic process, which demands effective, critical participation and significant involvement of the student in the face of challenges.

This approach is based on several educational theories. Based on the definitions of Berbel (2011), Dias (2017) and the pyramid of William Glasser (1998). Active methodologies arise with the objective of working on the student's protagonism in the teaching-learning process, making it possible to simulate real situations with the use of technology in the classroom. It seeks to highlight the student's autonomy in learning, with the teacher as an assistant, who can intervene during important moments, to assist in the construction of knowledge and deal with the questions that arise.

Valente (2014) highlights that the use of digital technologies can amplify the effects of active methodologies. By allowing the simulation of real contexts, the production of multimedia content, collaborative work and technological resources become powerful allies in the construction of more contextualized and interactive learning. In this sense, practices such as the flipped classroom, project-based learning, and gamification gain space because they are aligned with the language and interests of students.

However, the adoption of active methodologies is not without challenges. Its implementation requires careful planning, an investigative posture of the teacher and institutional conditions that favor innovation. It is a change that goes beyond the choice of techniques or tools: it involves transforming the way the school understands its formative function, valuing listening, collaboration and student protagonism as central elements of the educational process.

GAMIFICATION

Among the active methodologies applied to education, gamification stands out for its potential for engagement, as it encourages the active participation of students in the teaching-learning process. This characteristic is in line with the active methodologies described by Berbel (2011), which are based on the construction of knowledge through real or simulated experiences, enabling students to face challenges arising from the essential activities of social practice in different contexts.

The central theme of this work is gamification. The gamification proposed in this work favors the development of computational thinking by involving students in solving equations of the 1st degree through the virtual torque balance. During the activity, students practice skills such as decomposition, pattern identification, and logical reasoning, core elements of computational thinking applied to mathematics. In addition to promoting these skills, gamification also acts as an engagement strategy. In this sense, according to Busarello (2016), gamification can be structured as a system that uses playful scenarios to promote student engagement, combining game elements to stimulate both intrinsic and extrinsic motivation. However, the author warns that the excessive use of external rewards can, in some cases, reduce intrinsic motivation, requiring an appropriate balance between the two types of motivation. Intrinsic motivation is defined as self-interest and self-involvement, while extrinsic motivation is related to external rewards, such as grades or recognition (Guimarães, 2001).

According to Paula (2016), gamification involves more than just games, as it uses playful elements to achieve educational goals, going beyond simple entertainment. As required in computational thinking, its use, combined with technology, aims to promote an educational environment that strengthens skills such as logic, abstraction, investigation and pattern recognition, essential for the development of the ability to solve everyday mathematical problems.

According to Huang and Soman (2013), the application of this process involves five steps to make the educational process more effective. Figure 2 illustrates the gamification model described by Huang (2013), which served as a reference for structuring the stages of the present study. However, the methodology applied in this research presents specific adaptations, including the way of measuring the students' experience and the analysis of the data collected, as described throughout the text.

Figure 2: Representation of the stages of application of gamification developed by Soman Huang, 2013, adapted.

TARGET AUDIENCE AND CONTEXT

The teacher must know his target audience and align his strategies with the educational objectives, as proposed by Paulo Freire (2014), when he argues that education should be built from the student's culture and mediated by dialogue. In this sense, this work considers the premise that adolescents are currently strongly inserted in a digital culture permeated by electronic games and interactive environments. In addition, Deterding et al. (2011) argue that gamification, by employing typical elements of games, presents itself as a potential approach to promote engagement and motivation in different contexts.

DEFINITION OF LEARNING OBJECTIVES

In the context of gamification applied to education, it is essential to establish learning objectives that go beyond the simple memorization of procedures. It is expected that students will develop greater concentration, engagement and autonomy in carrying out activities, being able to interpret feedback and persist in solving problems. In the teaching of equations of the 1st degree, these objectives are related to the active construction of knowledge and the stimulation of algebraic thinking, through progressive challenges that promote logical reasoning and the understanding of fundamental concepts such as equality and balance.

STRUCTURING THE EXPERIENCE

The structuring of gamification must be efficient and adapted to the school environment, ensuring a fluid and effective application. The developer of the gamified project must involve everyone in the process, being careful not to generate demotivation in the participants, either due to excessive difficulties or the feeling that the process is boring or too easy. Therefore, it is essential to level the students from the beginning of the activity, starting with simpler challenges and progressively increasing the difficulty, in order to generate active student involvement.

It is worth noting that, in the teaching of equations of the 1st degree, the teacher can follow a didactic sequence that helps in the understanding of the theme before gamifying the content. Considering that students in the 7th grade of elementary school already have mastery of the four basic operations with natural numbers and integers, the teacher can structure the activities progressively, starting with simpler equations and gradually advancing to more complex challenges. According to Zabala (1998), the progressive organization of the contents favors the significant appropriation of concepts, especially when associated with methodologies that promote the resolution of problems in real or simulated contexts. This leveling makes it possible to monitor student engagement and learning, ensuring that pedagogical objectives are met. In addition, it provides students with the feeling that tasks are accessible and obstacles can be overcome, strengthening motivation and active participation.

IDENTIFICATION OF RESOURCES

Identification of resources Huang (2013) suggests five stages to assist in gamification:

- Tracking: tool to measure student progress.
- Score: Measures engagement in the game.
- Level: reflects performance and achievement of objectives.
- Rules: ensure a fair learning environment.
- Feedback: Providing quick responses to the learner is crucial for maintaining motivation and engagement.

Feedback should inform the student of successes and mistakes, as well as indicate progress and cumulative score. For the teacher, it is essential to monitor the overall progress, common mistakes and the time spent on tasks.

APPLICATION OF GAMIFICATION ELEMENTS

The elements of gamification are divided into:

- Own Elements: points, coins, levels and solving time that encourage individual competition and self-improvement.
- Social Elements: promote competition and interactivity in a group environment, with leaderboards.

It is up to the teacher to adapt the elements to the profile of the students, ensuring that the competition is fair and motivating. The teacher's challenge is to structure the process to maximize educational results, creating an active and engaging learning environment.

By following these steps, gamification can be implemented effectively, helping to achieve educational goals. The division of the game into levels and the implementation of well-defined rules, along with scoring and feedback, qualify the system and assist in the evaluation of students' progress.

RELATED JOBS

The torque balance model has been widely used in the teaching of equations of the 1st degree as a didactic resource to facilitate the understanding of the concept of equality and algebraic operations. According to Otten and Veldhuis (2019), this model allows students to visualize and internalize the balance between the sides of an equation, allowing for a deeper understanding of algebraic operations, rather than simple memorization.

The authors also point out different possibilities for implementation, such as physical, virtual, and designed versions, each with its advantages. For example, virtual scales allow interactive manipulation of equations and real-time feedback, which can improve the learning process. This methodology can improve the understanding of the concept of equality and the operations associated with the algebraic manipulation typical of solving equations.

Also noteworthy is the proposal by Marinho (2022), which uses the two-plate scale as a didactic resource for teaching 1st degree equations, especially aimed at students from the 7th to the 9th grade and the 1st year of high school. Its didactic sequence seeks to facilitate the visualization of equations through the idea of balance, promoting more interactive and concrete learning.

Similarly, Otten and Veldhuis (2019) value the scale model as a tool for internalizing the concepts of equality and balance, with different versions (physical, virtual, and drawn). However, both Marinho (2022) and Otten and Veldhuis (2019) maintain more traditional approaches, without considering elements such as negative numbers or gamification strategies — central aspects explored in this work.

In the context of teacher training for the use of digital technologies in teaching, a relevant work was presented by Coura et al. (2023). This study performs a systematic mapping of the literature, investigating practices that qualify elementary school teachers to use games and immersive interfaces, such as augmented and virtual reality, in their classes. While acknowledging the relevance and success of several initiatives, the paper makes a constructive critique, highlighting the need to broaden the focus beyond the teaching of computing tools. The authors suggest that the use of digital technologies should contemplate disciplines from different areas and emphasize the importance of a multidisciplinary approach, integrating computer professionals and teachers. In addition, the study points to the scarcity of concrete answers on how to structure training courses for basic education teachers that incorporate digital technologies, especially games and extended reality artifacts.

In this context, gamification has gained prominence as a pedagogical strategy that increases student engagement and motivation, especially in subjects such as mathematics. According to Coura et al. (2023), the implementation of game elements in the school environment can facilitate learning by transforming abstract concepts into practical and dynamic activities. The work highlights that teachers play an essential role in this process, being fundamental to create and mediate gamified experiences that connect content to students' realities. Adopting this approach requires not only knowledge of the available tools, but also training teachers so that they can apply them effectively, promoting meaningful learning.

Regarding the use of digital technologies in teaching, Compto and Sena (2019) discuss the relevance of gamification as a pedagogical strategy for teaching mathematics, highlighting its application at the Federal Institute of Amazonas. The authors point out that gamification promotes a more dynamic and interactive learning environment, stimulating the active participation of students and favoring their intrinsic motivation and engagement. In addition, the study reinforces that the adoption of gamified tools by teachers not only enhances learning, but also enables a differentiated approach to content considered challenging, such as mathematics. Like Coura et al. (2023), Compto and Sena (2019) also emphasize that it is essential to train teachers for the effective use of these technologies in the classroom, in order to ensure that such tools are meaningfully integrated into the teaching-learning process. Table 1 shows a summary comparing the studies mentioned.

Table 1: Comparison of Related Studies.

Author(s) / Year	**Scale Model Used from**	**Implementation (Physics, Virtual, Drawn)**	**Use from Gamification**	**Representation of Negative Numbers**	**Target audience**
Otten Et Al. (2019)	Torque Scale from	Physics, virtual drawn	No	No	Elementary School
Marine (2022)	Two-plate scale	Physics	No	No	7th to 9th grade and 1st year of High School

Oak (2023)	Virtual torque scale from	Virtual	No	Yes (Balloons)	Elementary School
Coura Et Al. (2023)	Digital technologies in teaching	Games and immersive interfaces (AR/VR)	Yes	Not specified	Training of teachers
Compto e Sena (2019)	No	No	Yes	Not specified	Middle school
Present study	Virtual torque scale from	Virtual	Yes	Yes (Balloons)	7th to 9th grade and 1st year of High School

In this study, an important innovation stands out: the introduction of gamification through the use of balloons to represent negative numbers, which allows students to intuitively visualize the concept of negative numbers and the balance on the scale. This representation provides a more practical and visual understanding of operations with negative numbers, something absent in previous works.

Gamification, by transforming the virtual scale into an interactive and competitive experience, aims to increase engagement and facilitate knowledge retention. We understand that feedback and progressive challenges create an experience that overcomes the static model discussed in Otten (2019) and Marinho (2022), focusing on motivation and greater depth in learning.

In the development of this work, it was important to consider similar approaches that also use the virtual scale in the teaching of equations. A relevant study is that of Carvalho (2023), entitled "The Teaching of Equations with the Use of a Virtual Scale" which includes the Representation of Negative Numbers. Carvalho (2023) explored the same virtual scale used in this work to teach equations of the 1st degree, although without the element of gamification, a resource introduced in the present work.

A differential of this virtual scale, also used by Carvalho (2023), is in the introduction of negative numbers, an innovative contribution made by a group of Brazilian researchers in 2017. This innovation was carried out by means of balloons that represent negative torques, since they force the rod of the scale to rotate in the opposite direction to that of the weights. With this, the virtual scale overcomes a limitation of traditional physical models, which have restrictions when dealing with negative numbers. This innovation allows students to better perceive how negative numbers represent actions that affect balance, an important aspect for understanding equations of the 1st degree.

METHODOLOGY

This section describes the methodological procedures adopted in this research, addressing the context of the investigation, the objective of the methodology, the description of the participants and the main tool used — the virtual torque scale. The stages of the gamified application in the classroom are also detailed, including the use of the application, practice with tablets, competition dynamics and simulations. The qualitative evaluation of the students' perceptions is discussed, followed by the methodological justification, based on the school context. Finally, the differentials and limitations of the research are presented. The section is divided into the following subsections: 4.1 Context of the Research; 4.2 Objective of the Methodology; 4.3 Description of Participants; 4.4 The virtual Torque Balance; 4.5 Simulations Performed and Application Stages; 4.6 Methodological Justification; and 4.7 Differentials and Limitations.

CONTEXT OF THE RESEARCH

The research was conducted in a public school located in the municipality of Rio Acima, Minas Gerais, with a little more than 10 thousand inhabitants. The institution serves elementary school II in the morning and afternoon shifts, in addition to Youth and Adult Education (EJA) at night. It is a small school, composed of fourteen regular classes in elementary II and four classes in the EJA modality.

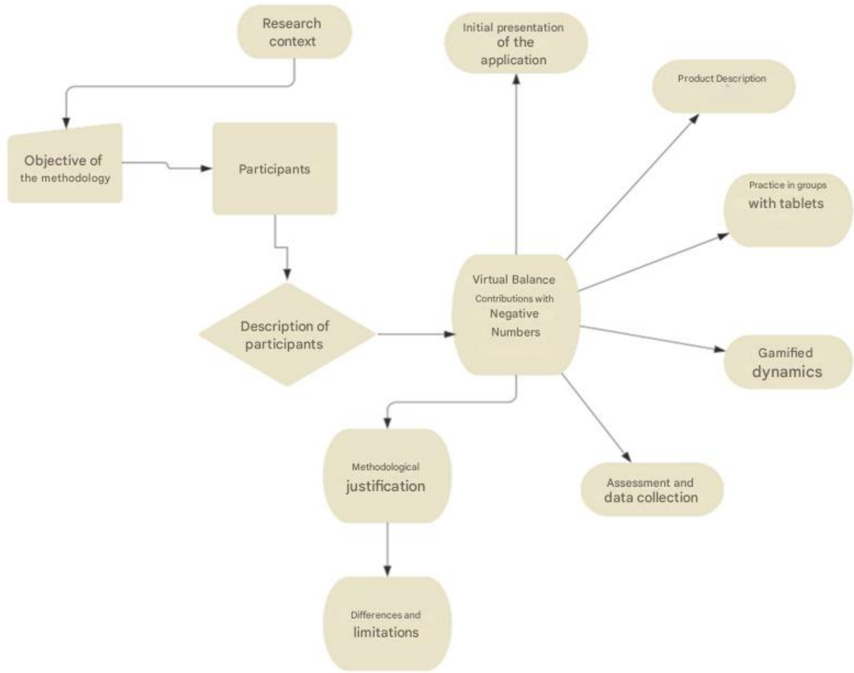
Most of the students belong to low-income families, predominantly in class D. The teacher responsible for applying the proposal — also a co-author of this work — has been working in the municipal network for 14 years, which provided greater knowledge of the local reality and the pedagogical needs of the students.

At the beginning of 2023, the municipal network provided tablets to all students at the school, authorizing students to take the equipment home. The institution also has good quality internet access and interactive screens of approximately 90 inches in each classroom, favoring the use of digital resources in collective and individual activities, 15 functional tablets were available at the time of application of the activity described in this research, which made it possible to carry it out in groups.

All activities developed during the investigation are in accordance with the regular attributions of the teacher in the classroom, as established by the Law of Guidelines and Bases of National Education (LDB, 9394/96) and by the National Common Curricular Base (BNCC, 2018). Among these attributions, the planning and execution of pedagogical activities, as well as the evaluation of student performance, stand out. In view of this, it is understood that the methodological proposal did not go beyond the scope of daily teaching practice, respecting the ethical principles pertinent to educational research.

Figure 3 illustrates the graphic representation of the research methodology applied in this work.

Figure 3: Graphic Representation of the Methodology developed by the authors.



OBJECTIVE OF THE METHODOLOGY

The main objective of this study was to implement a gamification proposal in the teaching of 1st degree equations in a 7th grade class of elementary school, through the use of an application that simulates a balancing scale. The intention was to promote a more interactive and dynamic approach, investigating how this strategy can influence students' motivation, engagement and understanding of the content, compared to more traditional teaching practices.

DESCRIPTION OF PARTICIPANTS

The participants of the research were 33 students from the 7th grade of elementary school, aged between 12 and 14 years. As mentioned earlier, this is a class belonging to a community with a socioeconomic profile predominantly in class D. Students were already familiar with the use of tablets and interactive screens in the classroom, due to the technological infrastructure made available by the school throughout the school year, which contributed to the receptivity and feasibility of the gamification proposal.

THE TORQUE BALANCE

One of these tools is the torque balance, which can be applied to the teaching of equations of the 1st degree. According to Halliday et al. (2016), torque is an action of rotating or twisting a body around an axis of rotation, produced by a force F. If F is exerted at a point given by the vector position r in relation to the axis, the modulus of torque is given by $\tau = F \cdot r$, where τ is the torque, F is the applied force and r is the lever arm (the perpendicular distance between the line of action of the force and the axis of rotation). A torque balance is a device that measures the balance between forces. The torque depends on the force applied and the distance between the fulcrum and the point of application of the force, generating a rotation. The greater the distance, the greater the torque, and consequently the less force required to obtain the same torque. This balance is directly related to the concept of center of gravity (CG), which is the point where the weight of a body can be considered concentrated. In the torque balance, the CG of each object determines how it contributes to the total torque, influencing the rotation and balance of the system. This concept is especially useful in teaching algebra, as the balance of forces and torques can be interpreted as a mathematical equation, helping to understand equality in equations.

By using balloons that represent negative numbers, students can visualize in a practical way the distinction between positive and negative numbers, which can facilitate the understanding of algebraic operations. This is particularly important, because the physical scale model does not allow such flexibility, in such an explicit way as in the virtual scale. This functionality, developed by the group of researchers, expands, therefore, the pedagogical possibilities of the tool.

Figure 4 illustrates the virtual torque scale, a digital device that was gamified in this study, highlighting its components:

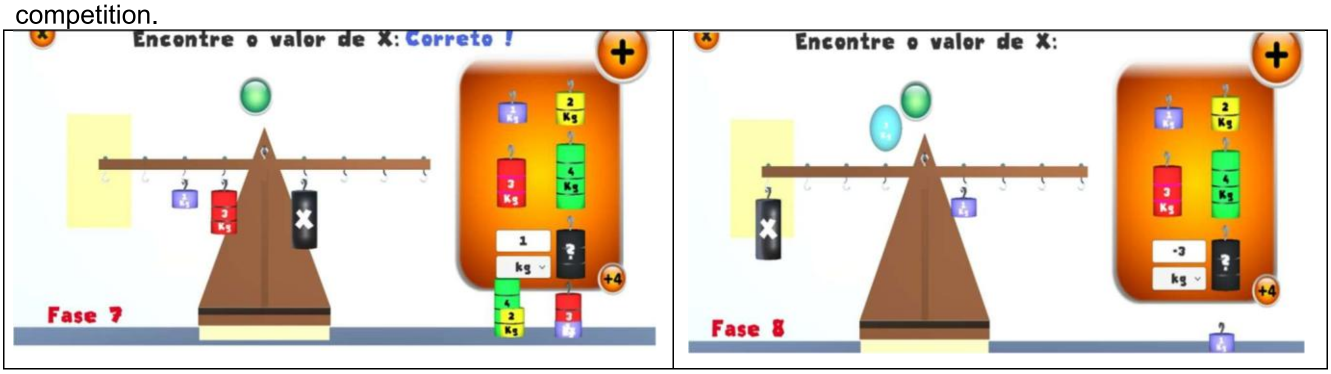
Figure 4: Representation of the Virtual Torque Scale developed by the authors.

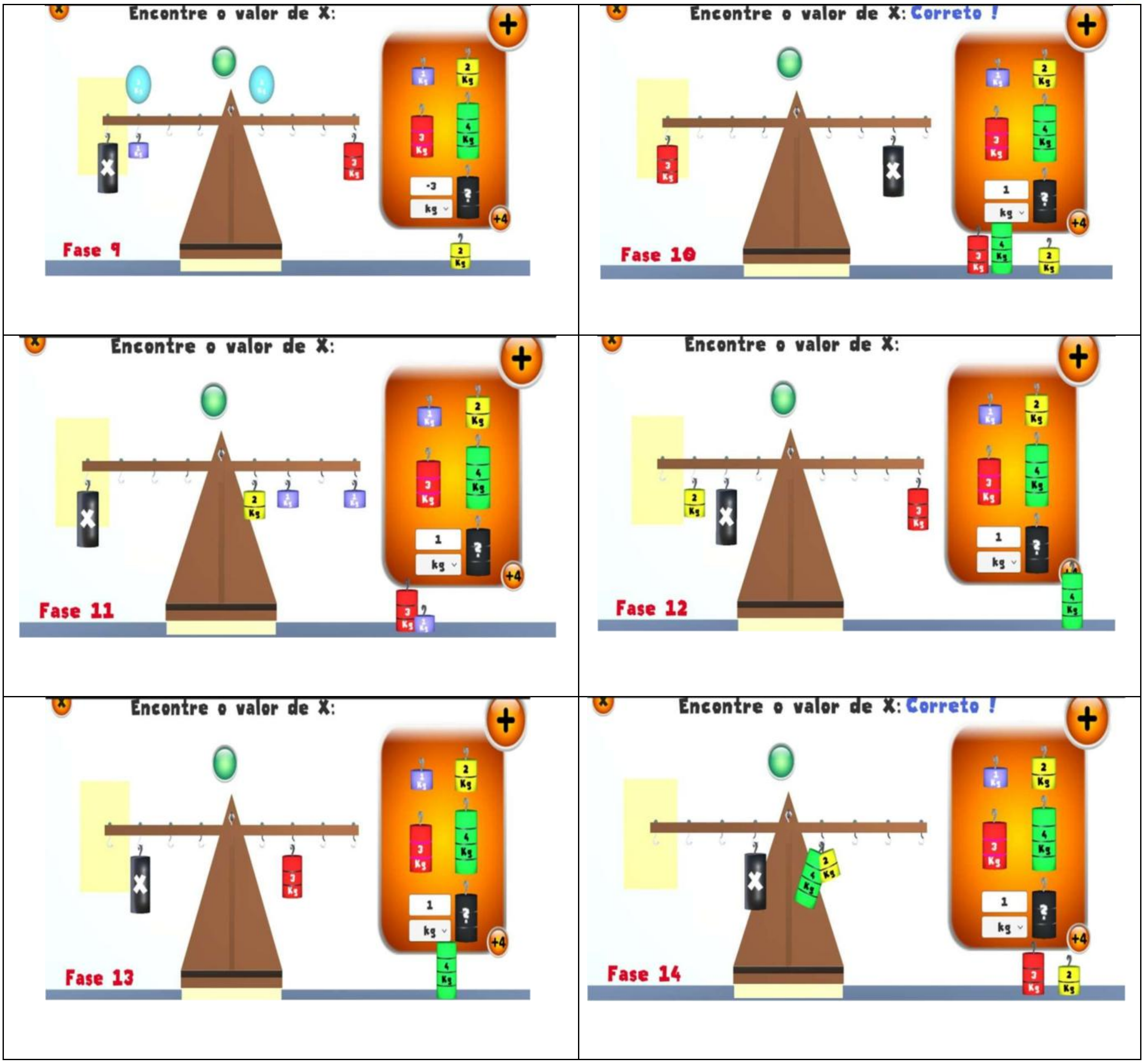
1- Green light LED indicates that the scale is in balance.
2- The (+) button opens the board on the right side, containing the weights of 1, 2, 3 and 4 kilos and allows you to generate other weights.
3- Weights of 1, 3 and 4 kilos already positioned on the hooks and thus generating downward forces, which represent positive values.
4- Balloon of –2 and –3 kilos already positioned on the hooks and thus generating upward forces, which represent negative values.
5- Unknown weight, (unknown x) the user must manipulate the weights to determine the value of x. In Figure we have phase 1 of the challenge mode, where x = 1.
6- Weight with question mark is responsible for generating any numerical value, be it weight or balloon.
7- The (+4) button is used to generate 16 weights of 1, 2, 3 and 4 kilos, which will be available to the user.

SIMULATIONS PERFORMED AND APPLICATION STAGES

Figure 5 presents examples of the simulations carried out with the students during the competition.

Figure 5: Simulations carried out with the students. Eight of the 16 challenges applied to students during the competition.





Developed by the authors.

Table 2 describes and analyzes the phases represented in the figure based on the equations of the 1st degree represented by the torque balance. Each phase presents a challenge involving weights (positive values) and balloons (negative values), which, when positioned at different distances from the center of the scale, form equivalent mathematical expressions.

Table 2: Equations implemented in the application.

Phase	Equation of the 1st degree	Resolution	Comment
7	$1{\cdot}2 + 2{\cdot}1 = 1{\cdot}x$	$2 + 2 = x \rightarrow x = 4$	Equation with all positive values. Ideal to start the equilibrium reasoning.
8	$4{\cdot}x + 1{\cdot}(-1) = 1{\cdot}1$	$4x - 1 = 1 \rightarrow 4x = 2 \rightarrow x = 0.5$	Enter negative number (balloon) and require algebraic manipulation with signs.

9	4·x + 3·1 + 3· (−1) = = 1· (−1) + 3·4	4x + 3 − 3 = −1 + 12 → 4x = 11 → x = 2.75	Involves cancellation of terms and numbers Negative. Stimulates attention and detailed analysis.
10	4·3 = 3·x	12 = 3x → x = 4	Classical equation of proportion. Good for strengthen multiplication and division.
11	4·x = 2·1 + 2·1 + 4·1	4x = 2 + 2 + 4 → 4x = 8 → x = 2	Shows sum of multiple terms on the right side. It works logical sequence and organization.
12	3·2 + 2·x = 4·3	6 + 2x = 12 → 2x = 6 → x = 3	It requires transposition of terms and final division. It reinforces equation solving techniques.
13	3·x = 2·3	3x = 6 → x = 2	Straightforward and simple equation. Establishes the concept of divide to isolate the x.
14	1·x = 2·1 + 4·1	x = 2 + 4 → x = 6	Unknown x is already isolated. Final phase that Reinforces balance in a clear and objective way.

Initial Application Presentation

The professor began with three lectures, each lasting 50 minutes, using the 90-inch interactive screen to present the operation of the balance scale. In these classes, the concept of balance and its relationship with the solution of equations of the 1st degree were addressed.

During the presentation, the resources available in the application were demonstrated, such as the representation of positive and negative numbers, the operations performed on the scale, and the accessible difficulty levels (Figure 4).

Product Description

The product developed in this research consists of a gamified methodology for teaching equations of the 1st degree, mediated by an interactive application that simulates a redesigned plate scale with increased positions for the weights on the rod. The proposal aims to offer students an interactive learning experience, seeking to expand conventional teaching, which is often limited in resources to illustrate algebraic manipulations involved in solving equations.

In the academic literature, the metaphor of the scale—especially that of two plates—often appears as a resource to help students understand the principle of equality in an equation. Andrews and Sayers (2012), for example, analyze how three European teachers use the image of the scale in their classes, even without taking a physical scale to the classroom. For these teachers, students are already able to activate the metaphor from their daily knowledge. This perception is shared by Stephens et al. (2020) and McFadden, Dufresne, and Kobasigawa (2010), who also highlight the usefulness of the plate scale in teaching elementary algebra.

In the present work, we opted for the use of the virtual torque scale, which is more complex than the two-plate one, as it allows the representation of the physical concept of torque ($\tau = F \cdot r$), in addition to enabling visual innovations, such as the use of balloons to represent negative numbers. This functionality does not find a direct parallel in physical scale models, but it expands the pedagogical possibilities of the resource, especially with regard to the offer of images associated with algebraic manipulations of positive or negative numbers.

We recognized that the use of physical scales in our work could have enriched the didactic experience, but the time allocated to the experiment did not allow for this approach. Still, according to our perception, the students demonstrated familiarity with the metaphor of the scale, intuitively understanding its dynamics. There were no indications of strangeness on their part regarding the presence of balloons or the structure of the application.

We believe that the didactic potential of gamified torque scales, especially in the differentiated representation of negative numbers, offers a promising field for future investigations. Further studies can explore systematic comparisons between physical and virtual scales, as well as take a deeper look at students' perceptions of the visual and mechanical elements of the simulation.

Group practice with the tablets

After the initial presentation of the virtual torque scale, the students participated in two practical classes (of 50 minutes each), with the objective of interacting directly with the application and experiencing the proposed challenges. The proposal aimed to investigate how students would react to the gamified application of an abstract concept such as the equations of the 1st degree, and whether the dynamics could favor understanding and engagement.

As there were only 15 tablets available, the class was divided into two groups (16 and 17 students). In each group, the students formed pairs to solve the challenges collaboratively, taking turns using the devices. This configuration ensured that everyone actively participated in the activity and allowed the observation of the interaction between peers, a relevant aspect for the analysis of perceptions during the experience.

Gamified dynamics

Gamification was structured as a competition in a tournament format, planned not only as a motivating resource, but as an instrument to observe how students would engage cognitively with the content and visualize, in practice, the concept of algebraic balance. In the first group (17 students), the competition took place in pairs, with the winners advancing to the following phases (eighth, quarterfinals, semifinals and final). A student who was unpaired in the first round was included by lottery. The same process occurred with the second group (16 students). At the end of this stage, the eight finalists in each group faced each other to define the winner of the tournament.

It is important to highlight that, as the students were disqualified, they began to act as observers of the matches in progress, assisting in the verification of the rules and ensuring the integrity of the disputes. This alternation of roles contributed to keeping all participants involved and offered additional opportunities for reflection on the proposed challenges.

The student who solved the phases of the game more efficiently and in less time advanced to the next stage. The competition, in addition to promoting enthusiasm and active participation, created an environment where it was possible to collect qualitative evidence about the effectiveness of the methodology adopted. Direct observation, spontaneous comments from students and records made during the activity provided subsidies for an analysis of students' perceptions regarding the clarity of concepts, understanding of the functioning of the virtual scale and the usefulness of algebraic visualization provided by the tool.

Although the present study did not apply a pre-test that allowed direct comparisons of performance, an exploratory approach was chosen, focusing on the investigation of students' perceptions and reactions to contact with the gamified resource. We believe that this methodological option, although limited in terms of impact measurement, is still valid in the context of a pedagogical experiment aimed at understanding the potential benefits of the virtual torque balance in the teaching of equations of the 1st degree.

Evaluation and data collection

The evaluation of the pedagogical intervention was carried out from a qualitative and descriptive approach, with the objective of investigating how students perceived the experience with the gamified virtual torque scale in the teaching of equations of the 1st degree. The data collection sought to raise evidence about the engagement, conceptual understanding and motivation of the students when interacting with this new didactic proposal.

At the end of the application, a questionnaire with 10 objective questions was delivered (see Appendix A), elaborated based on categories such as motivation, interest, engagement, fun, attention, feeling of challenge and difficulties faced. The questions were formulated with the aim of capturing students' perceptions about the learning experience lived, allowing comparisons with the traditional teaching method (blackboard), previously used in the classroom.

In addition to the questionnaire, systematic observations of the students' behavior during the activities were carried out, recording spontaneous reactions, informal comments and attitudes that revealed the level of involvement and understanding. These observations, although not formally structured in a protocol, served as complementary material for analysis, especially to interpret the answers to the questionnaire and support the conclusions presented.

It is important to highlight that, due to logistical limitations, as previously mentioned, it was not possible to apply a pre-test to assess the students' previous level of knowledge. For this reason, it is not intended here to establish causal relationships or to measure the effectiveness of the intervention with statistical rigor. Instead, the focus is on understanding students' perceptions of an innovative proposal, observing potential indications of pedagogical benefit that can guide more systematized future investigations.

This methodological choice does not compromise the value of the research, as long as its limits are recognized. It is believed that the collected data allow us to advance the discussion about the use of gamification and interactive visual representations, such as the torque balance, in the promotion of algebraic thinking, especially with regard to the understanding of equilibrium in equations of the 1st degree.

METHODOLOGICAL JUSTIFICATION

The choice to use the torque scale application as a central tool is based on its potential to graphically represent abstract concepts, such as balance and algebraic manipulations in equations of the 1st degree. The incorporation of gamification aimed to promote healthy competitiveness, combined with cooperation between peers, favoring the involvement of students in a dynamic and participatory environment. The use of tablets and the interactive screen provided greater technological accessibility, aligning with the possibilities of the available school infrastructure.

The present research adopts a qualitative approach, of descriptive and interpretative character, focusing on the analysis of students' perceptions about the didactic proposal. This developed proposal can be characterized as a pedagogical experiment, carried out with the aim of exploring the effects of the use of the torque balance in the teaching of equations of the 1st degree. Collection instruments were used to identify relevant information about the engagement and level of understanding of the students in the face of the differentiated strategy.

Thus, the application of a structured questionnaire with closed questions sought to collect data on aspects such as motivation, challenge and interest, offering the basis for a descriptive analysis that revealed trends and response patterns. Although the data were organized quantitatively, their reading was guided by the understanding of the meanings attributed by the participants to the experiences lived.

The research professor acted as a mediator during all stages of the intervention, leading the discussions, guiding resolution strategies and reinforcing mathematical concepts whenever necessary. With this, the methodology was planned to explore the potential of using digital technologies in the teaching of algebra, while respecting the operational and temporal limits of the school context, without losing sight of the commitment to investigative rigor.

DIFFERENTIALS AND LIMITATIONS

The school's technological infrastructure represented a relevant differential, enabling the use of tablets and a dynamic application in the teaching of equations. However, the limited number of devices required careful logistical planning, with the organization of the class into groups and rotation among students, which may have impacted the individual pace of exploration. Another aspect to be recognized as a limitation was the infeasibility of applying a pre-test, which compromises comparative analyses of conceptual learning before and after the intervention. Even so, the study contributes by offering indicators on the pedagogical potential of gamification associated with the virtual torque scale, serving as a basis for future investigations with greater experimental control.

DISCUSSION OF THE RESULTS

This section presents and analyzes the results obtained. The focus is on students' perceptions of engagement, motivation, and learning during the experience, based on data collected through questionnaires and classroom observations. The difficulties encountered in the application of the methodology, the adaptations made to the scale software, as well as the pedagogical hypotheses that emerged from the practice are also discussed. The following subsections are presented: 5.1 Expansion of Stages in the Game; 5.2 Difficulties encountered; 5.3 Impact of gamification on the teaching of equations; and 5.4 Perception of learning.

The results of the questionnaire applied to the class suggest a positive acceptance of the gamification proposal, indicating favorable perceptions by the students in relation to the learning environment created. Although the data point to signs of greater motivation, engagement, and attention during classes, it is not possible to affirm the effectiveness of the methodology based on these perceptions alone. Even so, such evidence leads us to consider that the application of gamification can arouse the interest of students, justifying new, more systematic investigations, including in other disciplines.

However, the analysis also highlights the need for a more personalized approach, considering that a minority found content more difficult or did not see significant improvements. These results suggest that the application of gamification should be carefully tailored to maximize the benefits for all learners, taking into account their different needs and learning styles.

From the students' answers, possibilities emerge that deserve to be investigated in future studies, such as the progressive customization of tasks and the diversification of game mechanics. It is possible that adjustable difficulty levels, individual or collaborative challenges, and the presence of immediate feedback directly influence student engagement and understanding. These hypotheses emerge from the experimentation reported in this study and can guide new iterations of the digital scale, especially if the objective is to increase its effectiveness in different school contexts. These considerations result exactly from the experimentation of the methodology, our contribution, and can be incorporated by the group that has been developing the digital scale for future explorations in other school contexts.

The combination of gamification with other pedagogical approaches can further expand its potential, especially if it is thought of as part of studies of active methodologies. However, this hypothesis needs to be tested in new contexts and with more robust methodological designs. Continuous listening to students, through more varied assessment instruments, can contribute to more precise adjustments in the proposal and to the consolidation of an approach that really favors learning. The present research does not offer definitive conclusions about these effects, but it points to promising paths to be deepened in future investigations.

We emphasize that the questionnaire focused on the students' perception of their willingness to get involved with the game. We noticed that they recognize a greater involvement with mathematics classes, however, although these perceptions indicate positive indications, it was not possible to develop systematic comparisons between classes studying equations with and without the use of the scale due to the limitations of our experiment. This comparison can be carried out in future investigations, which will allow a more careful perception of the effects of the use of the methodology in elementary school classes.

Our study also does not allow us to infer that gamification has expanded the perception that mathematics presents itself as a language capable of contributing to a better understanding of various aspects of the world around us. Mathematics, in the case of the scale, presents itself as a tool that allows the resolution of challenges related to balance. This subject can expand greatly from the analysis of practical situations in which the concept of torque is involved. We hope that students will be able to recover this concept in physics classes, for example, or even that mathematics teachers can expand their explorations of cases in physical reality that resemble what was studied on the torque scale. These reflections point, however, to the need for more research that could contribute to an expansion of the proposal of the software studied here.

Next, data from the questions that presented the main results of the questionnaire are highlighted, which offer clues about how the proposal was perceived by the participants.

In question 1, for example, 75.76% of students reported feeling "much more motivated" with gamification compared to traditional teaching. This data suggests that the use of playful and interactive elements can contribute to the increase of students' interest in Mathematics classes, although it is necessary to investigate whether this motivation is sustained in other learning situations and for longer periods.

Similarly, in question 3, 57.57% of the students stated that they felt "much more engaged", while 39.40% reported a moderate increase in engagement, totaling 96.97% of the students reporting an increase in engagement. These percentages reinforce the hypothesis that gamification can favor active participation in school activities. As the data collection was carried out after the experience, the results mainly reflect the perception of the students at that time. Future studies that include comparative instruments may deepen this analysis and allow a more accurate assessment of possible changes over time.

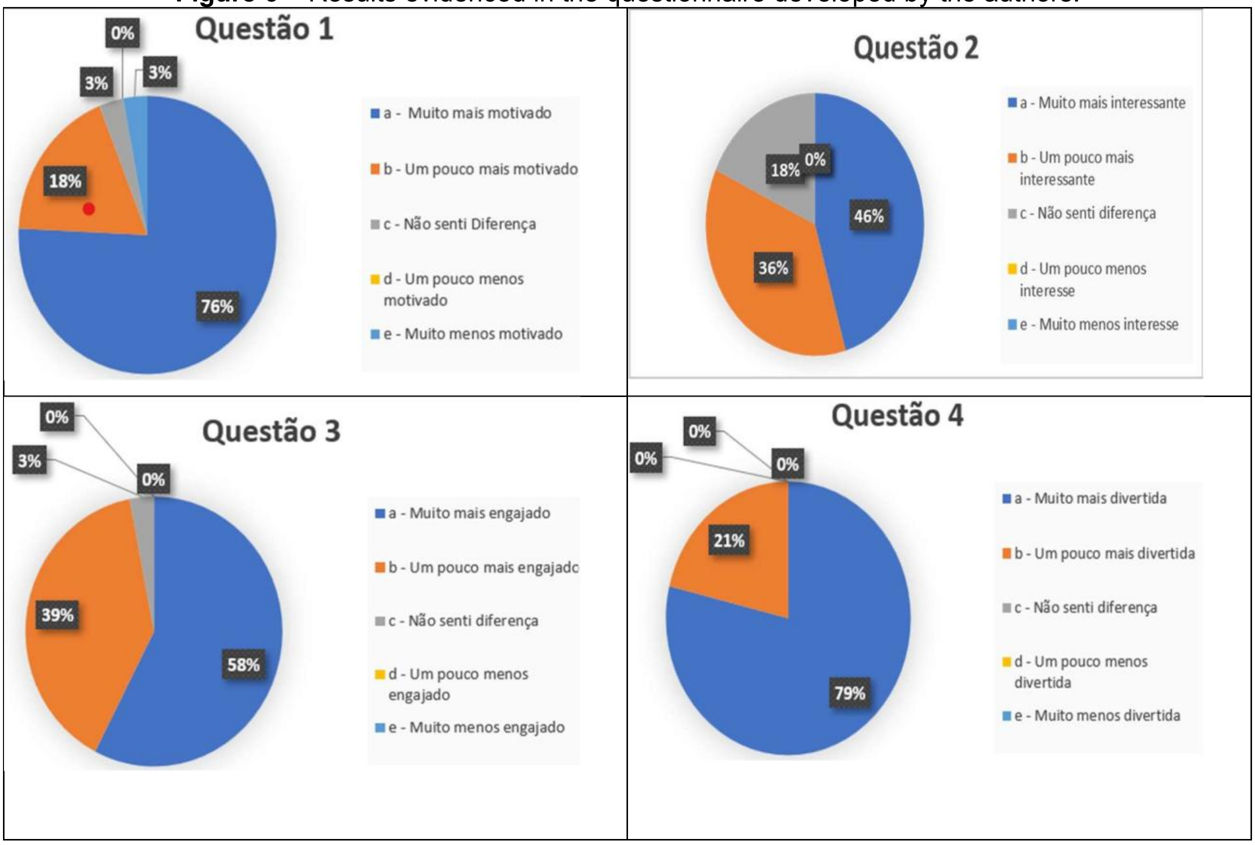
Question 5 showed that 51.51% of the students perceived a considerable improvement in their attention, while 36.36% noticed a slightly greater attention, totaling 87.87% of the students reporting an increase in attention. Although these numbers indicate a possible contribution of the proposal to the students' focus during the activities, it is important to consider that, because we did not use instruments prior to the intervention, the data obtained only reflect the moment after the application. Even so, they offer relevant evidence that can guide future investigations with more comparative designs.

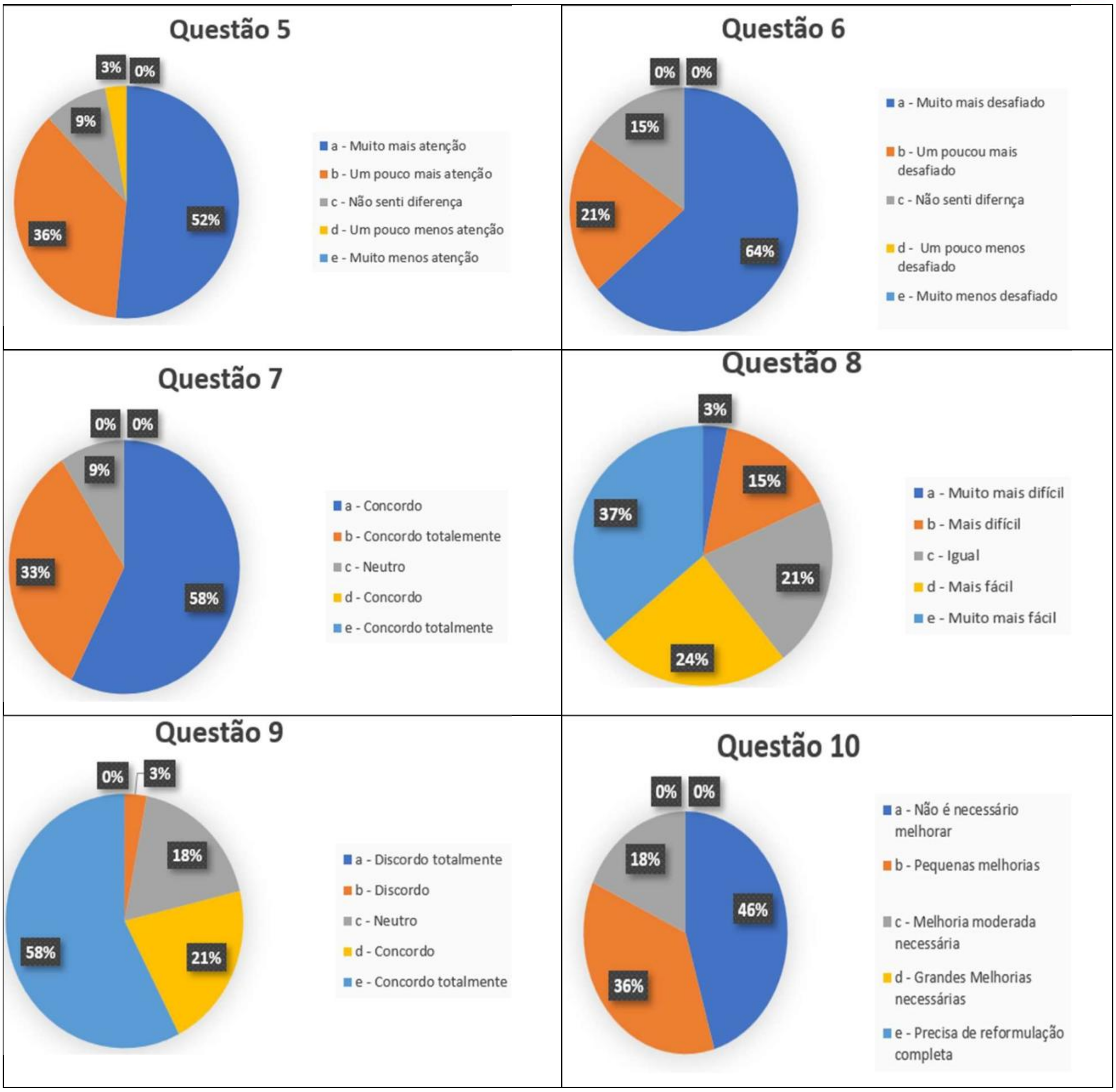
Question 6, which addressed the feeling of challenge, revealed that 63.64% of the students felt "much more challenged", while 21.21% indicated a moderate challenge, totaling 84.85% of the students reporting feeling challenged. This may indicate that the proposal stimulated problem solving and critical thinking, central components in the learning of Mathematics. The data obtained reflect the perception of the students at a specific moment of the experience, offering valuable clues about the potential of the proposal. In order to assess the impact on the conceptual domain more precisely, it would be interesting to carry out complementary studies with other types of instruments.

Finally, in question 9, 78.79% of the students expressed the desire to see gamification applied in other disciplines. This reinforces the perception that gamification not only improves the learning experience in mathematics, but can also be an effective methodology in other areas of knowledge.

The results evidenced in the questionnaire, applied to the students, are presented in Figure 6.

Figure 6 – Results evidenced in the questionnaire developed by the authors.





EXPANSION OF STAGES IN THE GAME

During the first class using the balanced scale application, it became evident that, although the tool facilitated the understanding of mathematical concepts, there was a need for greater complexity in the game phase. Originally, the app had only four steps, which generated constructive criticism from students. They reported that, although the app aided learning, the steps were short and easily memorized, especially when gamification was repeated in different rounds among peers.

In response to these observations, the app has been improved, going from 4 to 16 steps. The new phases were designed to follow a progression of difficulty, starting with simple equations, where the variable was present on only one side of the equality and the result involving only natural numbers, and progressing to more complex equations. Additional steps included scenarios where the variable appeared on either side of the equation, requiring students to solve equations with varying coefficients and outcomes that traverse the sets of natural, integer, and rational numbers. This degree of difficulty was increased to reinforce initial learning and, at the same time, challenge students to apply reasoning to other numerical sets. Table 3 presents these equations.

Table 3: Equations implemented in the application.

1) x = 3	9) 4x + 3 + 3· (−1) = = 1· (−1) + 12
2) 4x = 4	10) 12 = 3x
3) 4 + 1 = x	11) 4x = 2 + 2 + 4
4) 3x = 4 + 2	12) 6 + 2x = 12
5) x = 6	13) 3x = 6
6) x = 6 + 6	14) x = 2 + 4
7) 2 + 2 = x	15) 4x + 1 = 2x
8) 4x + 1· (−1) = 1	16) 2x + 6 = x + 2

DIFFICULTIES ENCOUNTERED

The expansion of the steps also revealed a technical limitation of the application: the inability to work with coefficients greater than 4. Due to the physical structure of the virtual model, which simulates a balance scale, the application has a limitation: it is based on the idea of weights and the distance of these weights in relation to the center of the scale to form equations, which makes it difficult to develop more complex expressions.

To overcome this limitation, an approach was adopted that allowed the creation of composite coefficients. The solution involved adding multiple weights in the same position on the scale. For example, to represent a coefficient of 8x, two 4x weights were placed in the same position, keeping the mathematical integrity of the equation within the constraints of the application. This solution not only expanded the possibilities of the app but also served as an educational tool to teach students about the composition of coefficients, enriching learning.

IMPACT OF GAMIFICATION ON THE TEACHING OF EQUATIONS

The application of gamification through the use of balanced scales enabled a new way of interacting with the content of 1st degree equations. During classes, it was possible to observe signs of greater engagement, motivation, and interest on the part of students — aspects often associated with active methodologies, such as gamification. These indications suggest that the scale model, by offering a concrete visualization of mathematical principles, can contribute to making the operations involved in solving equations more comprehensible.

By requiring students to perform symmetrical operations on both sides of the equation to maintain balance on the scale, the app appears to foster a more intuitive understanding of the concept of equality. This visual representation can function as a powerful metaphor for the balance needed in algebraic transformations. However, it is important to highlight that these observations are based on the specific experience reported in this study, and do not allow generalizations about the effectiveness of the tool.

The proposal of the scale, therefore, raises promising hypotheses about its potential as a didactic resource. Future investigations, with more controlled designs and varied assessment instruments, will be able to verify with greater precision the effects of gamification and the use of scales on the conceptual development of students. This study contributes with initial data and reflections that can guide these subsequent researches.

PERCEPTION OF LEARNING

During the application of the teaching of 1st degree equations through the active methodology of gamification, the introduction of balloons as a representation of negative numbers emerged as a relevant pedagogical innovation. In the activities with the virtual torque scale app, this visual and interactive representation allowed students a new way to access traditionally abstract concepts. The visual opposition between weights (positive numbers) and balloons (negative numbers) favored the understanding that the signs indicate opposite directions of rotation on the scale rod.

Based on the observations in the classroom, it was hypothesized that this approach contributed to facilitate learning. The students seemed to show greater interest in solving equations with negative numbers, even outside the digital environment, such as in activities carried out on the blackboard. In addition, the logic of torque equilibrium, central to the functioning of the scale, may have helped in the association between algebraic operations and concrete actions. Changes to one side of the rod required offsets on the other side.

With regard to the students' perception, the questionnaire applied at the end of the activities corroborated this perception. The results indicated that the students in the class showed a significant improvement in the understanding of equations with negative numbers. What's more, the introduction of balloons in the context of gamification increased motivation and engagement during lessons, and many students reported that the playful visualization of the concept was easier to assimilate compared to the traditional methodology. These results indicate a more meaningful and dynamic learning experience.

Another important finding is that the interaction with the balloons during the gamified activities encouraged the active participation of the students, promoting a more investigative and participatory approach to solving mathematical problems. In this sense, the use of balloons as a visual representation brought to light an innovative way of teaching equations, which motivated students to overcome challenges more confidently and autonomously. Thus, this innovation also contributed to the teacher attributing greater protagonism to the students.

Thus, the use of balloons in the virtual scale seems to have potential as a pedagogical resource, especially for students who demonstrate difficulties in understanding negative numbers in their abstract form. By transforming a traditionally challenging mathematical concept into a visual and interactive experience, gamification can contribute to making learning quadratic equations more accessible, promoting a possibly more intuitive and concrete understanding of negative numbers. Such evidence reinforces the need for future research that explores in greater depth the effects of this approach in different educational contexts.

Thus, although the data obtained were positive in all aspects evaluated, these results are interpreted as promising signs, and not as definitive validations. Cases of negative reception by students — which was not observed in this research — could indicate limitations of the approach, both in conceptual assimilation and engagement. For now, the data suggest that the methodology adopted has the potential to enrich the learning of equations of the 1st degree, especially with regard to the understanding of negative numbers.

CONCLUSIONS AND FUTURE WORK

The data obtained from the use of the application in the classroom suggest that gamification in the teaching of 1st degree equations has the potential to contribute significantly to deeper and more engaged learning, by stimulating the active participation of students in the proposed activities.

The contributions made in the application and its application in the classroom strengthened the hypothesis that gamification in the teaching of 1st degree equations is an effective tool to promote more dynamic and investigative learning. As discussed in this work, aspects mentioned in Section 2 are observed, which refer to active methodologies. It is perceived that the activity was centered on the student, the methods and techniques stimulated the interaction student x teacher, student x student and student x didactic material. The methodology established as a basis to explore the student's cognitive learning, through the resolution of real situations. Seeking collaborative and meaningful learning, critical reflection on the experience (this was the case of the students' reading in relation to only 4 stages of gamification), appropriation and division of responsibilities in the teaching-learning process, development of capacity for self-learning (each student is able to solve a problem situation in their own way, because to reach the solution of the scale there is no single path). It is believed that the use of the scale favored a greater retention of knowledge (especially in the understanding of the steps to solve a 1st degree equation), produced an improvement in interpersonal relationships, strengthening relationships between participants.

The expansion of the game's stages met the students' demand for greater challenges, while the adaptation to circumvent the technical limitations of the application demonstrated the flexibility and creativity necessary to optimize educational tools.

The integration between digital technologies and active methodologies, such as gamification, has shown promise in reconfiguring the role of teachers as mediators and facilitators of learning. In the context of this research, the use of the virtual torque scale stood out as a resource capable of stimulating the active participation of students and fostering a more dynamic and interactive environment. The data collected during the experiment indicate that the use of gamification may have contributed not only to increase engagement, but also to favor the construction of meanings about mathematical concepts, especially with regard to the idea of equilibrium in equations of the 1st degree. While these results are encouraging, further research would be needed to confirm such effects in broader or different contexts.

It is believed that the results obtained with the class suggest that, despite the individual differences between students, gamification was able to provide an accessible understanding of the equations of the 1st degree, while maintaining high interest and motivation throughout the activities. The data collected reinforce this perception, with 75.76% of the students reporting feeling more motivated and 78.79% showing interest in seeing the methodology applied in other disciplines. In addition, the feeling of challenge reported by 63.64% of the students indicates that the gamified approach can contribute to the development of critical thinking and mathematical problem solving. This experience reaffirms the potential of gamification as a promising methodology for teaching mathematics, demonstrating its ability to make learning more dynamic and engaging. The findings of this research also encourage further investigations into its application in different educational contexts, broadening future possibilities for teaching and learning.

For future work, one of the main directions will be the application of the gamification method used in this study in other grades and levels of education, verifying whether the positive results observed in the 7th grade can be replicated at different educational levels.

In addition, it will be relevant to broaden the focus of the study to topics beyond equations of the 1st degree, such as solving systems of equations, a field that has already been explored by one of the authors of this article, which can be adapted to active gamification methodology in different aspects of mathematics.

Another important possibility will be the improvement of the Virtual Torque Scale application used in this study. Future research may focus on including new functionalities, such as the possibility of working with variables with higher coefficients and different types of operations, or even integrating technologies such as augmented reality. This integration, combined with computational thinking, can make learning more interactive and dynamic, providing a richer experience for students.

Teacher training in the use of these digital tools is also crucial, as it expands pedagogical possibilities and allows teachers to develop innovative strategies for teaching first-degree equations. A long-term approach to implementing gamification and emerging technologies such as augmented reality can be important in assessing the impact on student performance, comparing it to traditional teaching methods, and providing a more continuous and in-depth analysis.

Finally, a promising line of research may be the integration of gamification with other educational technologies, such as distance learning platforms and artificial intelligence, to offer personalized feedback. The use of mobile devices can increase interactivity and expand the reach of the methodology, adapting it to the individual needs of students and promoting even more engaging and personalized learning.

REFERENCES

1. Altino Filho, H. V., Nunes, C. M. F., & Ferreira, A. C. (2020). Metodologias ativas no ensino de matemática: O que dizem as pesquisas? *Pensar Acadêmico, Manhuaçu*, *18*(1), 172–184.

2. Andrews, P., & Sayers, J. (2012). Teaching linear equations: Case studies from Finland, Flanders and Hungary. *The Journal of Mathematical Behavior*, *31*(4), 476–488. https://doi.org/10.1016/j.jmathb.2012.07.002

3. Berbel, N. A. N. (2011). As metodologias ativas e a promoção da autonomia de estudantes. *Semina: Ciências Sociais e Humanas*, *32*(1), 25–40. https://doi.org/10.5433/1679-0383.2011v32n1p25

4. Brasil. (1996). *Lei de Diretrizes e Bases da Educação Nacional (Lei nº 9394/96)*. Ministério da Educação.

5. Brasil. Ministério da Educação. (2018). *Base Nacional Comum Curricular*. Ministério da Educação.

6. Busarello, R. I. (2016). *Gamification: Princípios e estratégias*. Pimenta Cultural.

7. Carvalho, L. O. (2023). *O ensino de equações com a utilização de uma balança virtual* [Master’s thesis, Universidade Federal de São João del-Rei]. PROFMAT.

8. Compto, G. P., & Sena, F. L. L. (2019). Gamificação da matemática no Instituto Federal do Amazonas. In *Anais do VIII Congresso Brasileiro de Informática na Educação (CBIE 2019), XXV Workshop de Informática na Escola (WIE 2019)* (pp. 1299). Instituto Federal do Amazonas – Campus Tefé, Universidade Federal do Amazonas. https://doi.org/10.5753/cbie.wie.2019.1299

9. Coura, L., Delabrida, S., Fortes, R., Ilídio, R., Oliveira, S., & Castro, J. (2023). Qualificação de professores do ensino básico com jogos: Um mapeamento sistemático. In *Anais do XXXIV Simpósio Brasileiro de Informática na Educação (SBIE 2023)* (p. 825). https://doi.org/10.5753/sbie.2023.234978

10. D’Ambrosio, B. S. (1989). Como ensinar matemática hoje? *Temas e Debates*, *2*(2), 1–10.

11. de Azevedo Dias, H. D., & de Souza Araújo, J. (2024). Um relato de experiência do uso de metodologias ativas na construção do pensamento computacional paralelo. *International Journal of Computer Architecture Education*, *13*(1), 7–16. https://doi.org/10.5753/ijcae.20245339

12. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. (2011). Gamification: Using game-design elements in non-gaming contexts. In *CHI ’11 Extended Abstracts on Human Factors in Computing Systems* (pp. 2425–2428). ACM. https://doi.org/10.1145/1979742.1979575

13. Dias, S. R., & Chaga, M. M. (2017). Aprendizagem baseada em problema: Um relato de experiência. In *Práticas inovadoras em metodologias ativas* (p. 36).

14. França, R., & Tedesco, P. (2015). Desafios e oportunidades ao ensino do pensamento computacional na educação básica no Brasil. In *Anais dos Workshops do Congresso Brasileiro de Informática na Educação* (Vol. 4, No. 1, p. 1464). https://doi.org/10.5753/cbie.wcbie.2015.1464

15. Freire, P. (2014). *Aprendendo com a própria história*. Paz e Terra.

16. Glasser, W., & Glasser, C. (1998). *Choice: The flip side of control: The language of choice theory*. William Glasser Institute.

17. Guimarães, S. É. R. (2001). Motivação intrínseca, extrínseca e o uso de recompensas em sala de aula. In E. Boruchovitch & J. Bzuneck (Eds.), *A motivação do aluno: Contribuições da psicologia contemporânea* (pp. 37–57). Vozes.

18. Halliday, D., Resnick, R., & Walker, J. (2016). *Fundamentos de física – Mecânica* (9th ed.). LTC.

19. Huang, W. H.-Y., & Soman, D. (2013). Gamification of education. *Report Series: Behavioural Economics in Action*, *29*(4), 37.

20. Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira. (2023, December 5). Divulgados os resultados do Pisa 2022. https://www.gov.br/inep/pt-br/assuntos/noticias/acoes-internacionais/divulgados-os-resultados-do-pisa-2022

21. Johnson, L., Adams Becker, S., Estrada, V., & Freeman, A. (2014). *NMC Horizon Report: 2014 Higher Education Edition*. The New Media Consortium.

22. Marinho, V. (2002). *Sequência didática para utilização da balança de dois pratos na matemática* [Undergraduate thesis, Universidade Federal de São João del-Rei]. Advisor: Sonní Lemos Barreto; Juliana Schivan.

23. Mcfadden, G. T., Dufresne, A., & Kobasigawa, A. (1987). Young children's knowledge of balance scale problems. *The Journal of Genetic Psychology*, *148*(1), 79–94. https://doi.org/10.1080/00221325.1987.9914536

24. Otten, M., Van den Heuvel-Panhuizen, M., & Veldhuis, M. (2019). The balance model for teaching linear equations: A systematic literature review. *International Journal of STEM Education*, *6*, 1–21. https://doi.org/10.1186/s40594-019-0183-2

25. Paula, F. L. (2016). *Gamificação no ensino de língua portuguesa: Proposta de atividades com gêneros jornalísticos e midiáticos* [Master's thesis, Universidade do Estado do Rio Grande do Norte].

26. Prikladnicki, R., Albuquerque, A. B., von Wangenheim, C. G., & Cabral, R. (2009). Ensino de engenharia de software: Desafios, estratégias de ensino e lições aprendidas. In *FEES – Fórum de Educação em Engenharia de Software* (pp. 1–8).

27. Stephens, A., Sung, Y., Strachota, S., Torres, R., Morton, K., Gardiner, A. M., Blanton, M., Knuth, E., & Stroud, R. (2022). The role of balance scales in supporting productive thinking about equations among diverse learners. *Mathematical Thinking and Learning*, *24*(1), 1–18. https://doi.org/10.1080/10986065.2020.1793055

28. Valente, J. A. (2014). A comunicação e a educação baseada no uso das tecnologias digitais de informação e comunicação. *UNIFESO – Humanas e Sociais*, *1*(1), 141–166.

29. Vianna, Y., Vianna, M., Medina, B., & Takanaka, S. (2013). *Gamification, Inc.: Como reinventar empresas a partir de jogos*. MJV Press.

30. Zabala, A. (1998). *A prática educativa: Como ensinar*. Artmed.

APPENDIX A - QUESTIONNAIRE APPLIED TO STUDENTS

Question	Alternatives
1. Did you feel more motivated to learn during the gamification class compared to the class on the blackboard?	a) Much more motivated b) A little more motivated c) I didn't feel any difference d) A little less motivated e) Much less motivated
2. Did the gamification class arouse your interest in the content of 1st degree equations the most?	a) Much more interest b) A little more interest c) I didn't feel any difference d) A little less interest e) Much less interest
3. Did you feel more engaged and participatory during the gamification class?	a) Much more engaged b) A little more engaged c) I didn't feel any difference d) A little less engaged e) Much less engaged
4. You Found than the Did gamification make the class more fun?	a) Much more fun b) A little more fun c) I didn't feel any difference d) A little less fun e) Much less fun
5. Did you find that gamification helped keep your attention throughout the class?	a) Much more attention b) A little more attention c) I didn't feel any difference d) A little less attention e) Much less attention
6. Did you feel more challenged and stimulated with the gamification class?	a) Much more challenged b) A little more challenged c) I didn't feel any difference d) A little less challenged e) Much less challenged
7. Do you think gamification makes it easier to understand the concepts?	a) I totally disagree b) Disagree c) Neutral d) Agree e) I totally agree
8. How did you feel about the difficulty of the content when using the app compared to the traditional class?	a) Much more difficult b) More difficult c) Equal d) Easier e) Much easier

9. Would you like other disciplines to use gamification as well?	a) I totally disagree b) Disagree c) Neutral d) Agree e) I totally agree
10. What do you suggest to improve classes with gamification?	a) No improvement needed b) Minor improvements c) Moderate improvement required d) Major improvements needed e) Needs complete overhaul