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GAMIFIED APPROACHES TO PHYSICS TEACHING: DIDACTIC SEQUENCE FOR THE STUDY OF SATELLITES AND GPS

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ABSTRACT

The present work addresses the use of gamification and Role Playing Game (RPG) as methodologies for teaching Physics, specifically in the study of satellites and the Global Positioning System (GPS). The issue-problem raised was the difficulty of keeping students motivated and engaged with abstract concepts of Physics in high school. The objective of the research was to develop, implement and evaluate a didactic sequence that integrates these concepts using interactive practices, with a focus on increasing students' motivation and cognitive development. The methodology was based on the references of the National Common Curricular Base (BNCC), which promotes active learning and student protagonism, and on Howard Gardner's Theory of Multiple Intelligences, which values different ways of learning. The didactic sequence, called Ultra-Secret Aerospace Mission (M.A.U.S.), used simulators, Google Maps and practical activities in a gamified context. The results indicated a significant improvement in the students' understanding of physical concepts. Engagement and motivation also grew substantially. Despite the challenges related to access to technologies, the methodology proved to be effective in teaching abstract concepts and promoting collaborative work. Findings suggest that the approach can be adapted to other disciplines and educational contexts, as well as pointing to future research on the application of emerging technologies, such as augmented reality, in teaching.

Keywords: Physics Teaching, GPS, Satellite Launch, Didactic Sequence, Meaningful Learning.

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Revista ARACÊ
ISSN: 2358-2472

INTRODUCTION

The Physics teacher in high school often faces the challenge of keeping students engaged and interested in abstract concepts and, sometimes, distant from their everyday reality. This scenario is aggravated when it comes to complex topics, such as the launch of satellites and the functioning of the Global Positioning System (GPS) (Woolnough, 1998; Bravo et al., 2017; Berge et al., 2019; Bouchée et al., 2021).

These topics, although increasingly present in modern life, are taught in a way that does not connect students in a practical way with their applications in the real world. In addition, difficulties in integrating innovative pedagogical approaches into the traditional curriculum limit students' active learning and motivation for scientific topics (Aji and Khan, 2019; Ferreira and Ferreira, 2019; López-Fernández et al., 2019; Ma et al., 2021; Oliveira et al., 2022).

The main motivation of this study arose from the need to find new educational approaches that can not only bring students closer to complex physical concepts, but also engage them more actively in the teaching-learning process. The use of methodologies such as gamification and Role Playing Game (RPG) was seen as a potential solution to transform the teaching of Physics into something more interactive, contextualized and relevant for students. These approaches aim to increase student engagement and motivation, promoting more meaningful learning (Ferreira and Ferreira, 2019; Saleem et al., 2021; Oliveira et al., 2022; Katanosaka et al., 2023).

In this context, the use of the theme of satellites and GPS was chosen for its practical relevance, since these systems are widely used in everyday technologies such as smartphones and navigation devices. The main objective of this work was to investigate, develop and evaluate a didactic sequence that would integrate the launch of satellites and the Global Positioning System (GPS) to the teaching of Physics, using methodologies to improve the understanding and engagement of students. In this context, the educational product developed, called Top-Secret Aerospace Mission (M.A.U.S.), was implemented in a high school class, promoting a learning experience based on RPG.

The research sought not only to improve students' conceptual understanding of space physics, but also to evaluate the impact of the didactic sequence on motivation and cognitive development, as well as on their perception of the practical importance of the concepts addressed.

Revista ARACÊ
ISSN: 2358-2472

These issues were explored through the analysis of the results obtained during the application of the didactic sequence, which involved the simulation of satellite launches, solving practical problems and using digital tools such as Google Maps and simulators.

GUIDELINES OF THE NATIONAL COMMON CURRICULAR BASE (BNCC)

The research project was aligned with the guidelines of the National Common Curricular Base (BNCC) (Brazil, 2018), by promoting active learning, focused on student protagonism, the use of digital technologies and the integration of scientific and technological knowledge by stimulating investigative skills, scientific competencies and the ability of students to interpret, experiment and argue about the concepts of Physics in a practical and contextualized way. In the context of the proposed didactic sequence, these principles were applied through interactive and practical activities that connect the launch of satellites and the operation of GPS with the daily lives of students.

The didactic sequence proposed in the study was elaborated in accordance with the general and specific competencies established by the BNCC. In particular, scientific, critical and creative thinking competence was addressed by promoting the investigation and resolution of practical problems related to the launch of satellites and the operation of the Global Positioning System (GPS).

This focus aimed to encourage students to interpret physical phenomena in a critical way, using scientific knowledge to make responsible and reasoned decisions. The investigative dimension of Natural Sciences, as described in the BNCC, was also contemplated, encouraging students to identify problems, formulate questions, propose hypotheses and elaborate explanations.

The didactic sequence stimulated these investigative practices by including activities that involved the simulation of satellite launches and the use of digital tools, such as Google Maps. Through these activities, students were able to experiment with scientific modeling processes and make predictions based on experimentally collected data.

One of the fundamental principles of the BNCC is the promotion of student protagonism, that is, the active participation of students in the learning process. This principle was applied in the project through the use of gamification and Role Playing Game (RPG), which encouraged students to take on the role of scientists and make decisions related to launching satellites in an immersive narrative. This approach allowed students to

Revista ARACÊ
ISSN: 2358-2472

not only receive knowledge passively, but also actively build on their learning, exploring different possibilities and solving complex problems in a collaborative context.

By working as a team, students were able to develop skills such as communication, group work and decision-making, aspects emphasized by the BNCC as essential for the integral formation of the student. In addition, the didactic sequence was planned to integrate the use of digital technologies in the teaching of Physics, a component also reinforced by the BNCC as an effective means to connect school content to the daily lives of students and prepare them for the contemporary technological reality.

Regarding the curricular contents, the BNCC proposes the integration of different areas of knowledge, and the didactic sequence adopted this guideline by connecting Physics topics (such as gravitation and the movement of projectiles) with technology (use of satellites and GPS). This interdisciplinarity is crucial for students to understand scientific knowledge as something applicable to real situations, such as the daily use of navigation and location systems.

The specific skills of the area of Natural Sciences and its Technologies were also addressed. For example, the ability to analyze and interpret the movements of objects based on gravitational interactions was worked on in a practical way, using simulators to represent the movement of satellites.

The BNCC establishes that students must be able to interpret natural phenomena based on scientific models and empirical data, and this was clearly applied in activities that involved the analysis of launch trajectories and the calculation of parameters such as the speed and altitude of satellites.

Another important aspect of the BNCC addressed in the project was the use of digital tools in the teaching-learning process. The BNCC suggests that students should be exposed to technologies that allow the simulation and experimentation of scientific phenomena in a practical and visual way.

In the didactic sequence developed, the use of simulators such as PhET (Physics Education Technology) allowed students to experiment in an interactive way the concepts of Physics related to the launch of satellites. These tools are particularly valuable because they offer students the opportunity to test hypotheses, observe results in real time, and thus deepen their understanding of the concepts covered.

The BNCC also emphasizes argumentation competence, encouraging students to formulate and defend arguments based on scientific evidence. The didactic sequence explored this competence by encouraging students to discuss and justify their choices during the satellite launch simulation activities. The students needed to use concepts from Physics to support their decisions, practicing the construction of logical reasoning and the use of scientific language to communicate their ideas.

HOWARD GARDNER'S THEORY OF MULTIPLE INTELLIGENCES

The Theory of Multiple Intelligences, proposed by Howard Gardner, revolutionized the understanding of how people learn and process information. According to Gardner, intelligence is not a single general ability measured by IQ tests, but rather composed of different forms of intelligence, each responsible for a specific set of abilities (Gardner, 1994).

These multiple intelligences reflect the diversity of human competencies and the variety of ways in which learning can occur. Howard Gardner's Theory of Multiple Intelligences proposes a broader and more diverse view of human intelligence, challenging the traditional IQ-centric approach. While the theory has been widely adopted in education, promoting practices that value different forms of intelligence, it still lacks robust empirical validation. However, its impact on the way we understand and approach education is undeniable, encouraging greater personalization and inclusion in teaching (Avery, 1993; Sternberg, 1994; Allix, 2000).

Gardner initially identified seven types of intelligence, and later added others, adding a total of nine intelligences.

- Logical-Mathematical Intelligence: Related to the ability to reason logically and the ability to solve mathematical problems.
- Linguistic Intelligence: Involves sensitivity to spoken and written language.
- Spatial Intelligence: Refers to the ability to perceive and manipulate three-dimensional space.
- Body-Kinesthetic Intelligence: It is linked to the use of the body to solve problems or create products.
- Musical Intelligence: Related to the ability to understand, create, and appreciate musical patterns.
- Interpersonal Intelligence: This refers to the ability to understand and interact effectively with others.

Revista ARACÊ
ISSN: 2358-2472

- Intrapersonal Intelligence: Related to the ability to introspect and understand one's own emotions, motivations, and desires.
- Naturalistic Intelligence: Introduced later, this intelligence involves the ability to identify and categorize elements of nature, such as plants, animals, and ecological patterns.
- Existential Intelligence: Although less discussed, this intelligence refers to the ability to deal with deep questions of human existence, such as the meaning of life and death.

Gardner's main contribution to education was the idea that every student learns differently. While the traditional education system tends to primarily value logical-mathematical and linguistic intelligence, Gardner argues that all forms of intelligence should be recognized and developed in the school environment. This has led to educational practices that consider the various ways of learning and knowing, adapting curricula, instruction, and assessments to better meet the individual needs of students (Eisner, 1994; Gardner, 1994; Anmol, 2019; Cavas and Cavas, 2020).

By identifying the dominant intelligences of each student, the teacher can personalize his pedagogical approach, offering activities that promote not only conceptual learning, but also individual engagement (Avery, 1998; Eisner, 2004; Anmol, 2019).

For example, in a Physics class using the Theory of Multiple Intelligences: students with logical-mathematical intelligence can benefit from problems involving formulas and calculations related to study content (Rahbarnia et al., 2014; Azinar et al., 2020; Mayasari et al., 2021; Nurhajarurahmah, 2021); students with spatial intelligence may be challenged to draw diagrams or use simulators (Hernández-Torrano et al., 2014; Ahvan and Pour, 2016; Nurhajarurahmah, 2021); Students with interpersonal intelligence may be encouraged to work in teams to solve challenges, while those with intrapersonal intelligence may be encouraged to reflect on how the knowledge gained impacts their perception of the world (Barrington, 2004; Lai and Yap, 2016; Cavas and Cavas, 2020).

The application of this theory at different educational levels and contexts has shown significant benefits, especially in terms of inclusion and pedagogical effectiveness.

Revista ARACÊ
ISSN: 2358-2472

GAMIFICATION AND ROLE PLAYING GAME (RPG)

These methodologies make it possible to increase engagement, motivate students, and make learning more interactive and meaningful. Below, these two concepts and their application in the described project are detailed.

Gamification refers to the application of game design elements in non-playful educational contexts, with the aim of making the learning process more attractive and motivating, and several studies have investigated the effects of gamification on student motivation, engagement, and learning outcomes. (Buckley and Doyle, 2016; Zainuddin, 2020; Manzano-León et al., 2021).

Gamification is a pedagogical approach that uses elements of games to increase student motivation and engagement in educational activities. The central idea of gamification is to increase students' intrinsic motivation, making them more involved in activities and feel challenged to meet goals and achieve educational objectives through a fun and competitive approach (Buckley and Doyle, 2016; Xu et al., 2021; Jones et al., 2022; García-López et al., 2023).

Role Playing Game (RPG) is an educational methodology in which students take on fictional roles and participate in immersive narratives, with the aim of solving problems and making decisions based on the context of the game and this approach has gained increasing attention in the field of education due to its potential to engage and motivate students. (Bagès et al., 2020; Gatsakou, 2021; Ortolani and Ortolani, 2021; Afandi et al., 2022).

However, the effectiveness of this methodology depends on careful implementation and proper guidance to ensure that educational objectives are achieved. With more research and development, RPGs can become a standard tool in educational settings, benefiting both students and educators (Wang, 2020; Cullinan and Genoa, 2023).

The combination of gamification and role-playing in physics teaching enables several educational benefits:

- Engagement and Motivation: gamification and role-playing enable a more attractive learning environment, where students feel more involved in activities and motivated to learn (Subhash and Cudney, 2018; Sailer and Homner, 2019; Zainuddin et al., 2020; Zhang et al., 2021).
- Meaningful Learning: through RPG, students can connect the theoretical concepts of Physics with practical and real situations, making learning more relevant and

Revista ARACÊ
ISSN: 2358-2472

applicable to the world outside the classroom (Wegener, 2012; Boas et al., 2017; Sitko and Costa-Lobo, 2018).

- Collaboration and Teamwork: the RPG format enables teamwork, where students need to collaborate to solve complex problems. This helps to develop interpersonal skills, as well as facilitate the exchange of knowledge among students (Zhang, 2013; Riivari, 2021).
- Cognitive Development: the playful approach promotes the development of cognitive skills, such as critical thinking and problem-solving, as students needed to apply theoretical concepts to make decisions in the game, improving their ability to think logically and creatively (Sailer and Homner, 2019; Fonseca, 2023; Lukman, 2023; Samala, 2023).
- Autonomy and Student Protagonism: both gamification and RPG have placed students at the center of the teaching-learning process, stimulating protagonism and autonomy. Students are not mere receivers of information, but active actors who build their own knowledge throughout the game and the proposed activities (Yildirim, 2017; Zainuddin et al., 2020; Montenegro-Rueda et al., 2023).

In this work, the application of the Theory of Multiple Intelligences was enhanced by gamification and the use of RPG, through activities and approaches provided by the didactic sequence based on RPG, as they enable students to assume the roles of scientists, working collaboratively and using their individual skills. In addition, the gamified format offers rewards and challenges that stimulate both logical and creative learning, respecting the variations in the forms of learning among students.

METHODOLOGY

The research was carried out within the scope of the National Professional Master's Degree in Physics Teaching (MNPEF), within the graduate program of the State University of Ponta Grossa (UEPG), and had as its place of implementation the Colégio Estadual Conselheiro Carrão, located in Curitiba-PR.

The research was carried out with students in the third year of high school, whose age range varies between 16 and 18 years old. These students mostly came from an educational context typical of public schools, facing challenges such as lack of motivation for learning and difficulties in understanding abstract concepts related to Physics.

Revista ARACÊ
ISSN: 2358-2472

The methodology applied in this work included a didactic sequence, which incorporated a variety of activities that allowed students to explore different types of skills and intelligences. By working as a team and taking on specific roles, students were encouraged to develop both their individual and collective competencies, favoring an inclusive and collaborative learning process.

The concepts of gamification and Role Playing Game (RPG) were used as methodological tools to increase student engagement. Gamification was used to make the teaching process more dynamic and motivating, using typical game elements, such as challenges, goals, and rewards, to encourage the active participation of students (reference).

The RPG was used in a more immersive way, where students took on the roles of scientists responsible for space missions, simulating the launch of satellites and the use of GPS technologies. This teaching format was essential to promote contextualized learning, allowing students to experiment and apply Physics concepts in a practical and engaging way.

Gamification has been implemented through the creation of clear goals, missions, and reward points. Students were encouraged to complete specific tasks, such as solving physics problems related to satellite launches and GPS operation, in a game-like format, where each achievement yielded rewards, such as advancing through learning levels or obtaining symbolic prizes.

This approach significantly increased students' interest and motivated them to solve complex problems, as learning was transformed into an engaging activity, with elements of competition and cooperation and provided an immersive learning experience, where students had to use their knowledge of Physics to make decisions during the mission.

The narrative of the RPG was called "Ultra-Secret Aerospace Mission (M.A.U.S.)" and was applied to a class of the third year of high school at a public school in the city of Curitiba - PR. In this activity, students played the roles of scientific officers in charge of planning and executing the launch of satellites, following minimal instructions from a professor who acted more as a facilitator of the process.

The RPG was used as a central tool to engage students in a fictional scenario in which they assumed the role of scientists responsible for launching satellites and operating the GPS system, which allowed students to work as a team, develop problem-solving and critical thinking skills, and apply theoretical concepts of physics in a practical way.

The students needed to calculate satellite trajectories, determine the optimal time for launch, and predict the behavior of the GPS system, using simulators to test their hypotheses. Each student had a specific role in the mission, and collaboration between the different scientists was crucial to the success of the operation.

THE DIDACTIC SEQUENCE: TOP-SECRET AEROSPACE MISSION (M.A.U.S.),

The didactic sequence focuses on the teaching of Physics concepts related to the launch of satellites and the Global Positioning System (GPS), was developed in the format of gamification and RPG. The following are the details of the structure and application of this didactic sequence.

The didactic sequence was organized as an immersive narrative in RPG format, called Ultra Secret Aerospace Mission (M.A.U.S.), where students took on the roles of scientists responsible for a space mission.

The main objective of this sequence was to integrate complex physical concepts into high school, using an approach that connects theoretical content to practical application, making them more accessible and interesting for students.

The didactic sequence begins with an introduction to the theme of satellite and GPS launches, highlighting their practical relevance in the daily lives of students, such as the use of navigation systems on smartphones and communication technologies. The idea was to show how these systems depend on physical concepts that students could explore during activities.

In the introduction, students were introduced to the RPG's narrative, being divided into teams and taking on the role of scientific officers with the mission of launching satellites to support a fictional agency. At this point, a briefing of the mission was made, detailing the role of each team and its objectives.

The students were divided into teams and each one was given a specific role within the RPG narrative. The functions varied between: Physics officers: responsible for calculating the satellite's launch parameters, such as trajectory and initial speed; Communication officers: in charge of determining the position of satellites and ensuring GPS signal coverage; and Mission Officers: overseeing the overall operation and strategic decision-making for mission success. This division of roles allowed the students to work as a team, collaborating with each other to solve problems and achieve mission objectives.

Revista ARACÊ
ISSN: 2358-2472

The didactic sequence was structured in order to integrate the physical concepts related to the launch of satellites and the operation of GPS, such as: Universal Gravitation; Projectile movement; and Electromagnetic waves and GPS. These concepts were explored through practical activities and experiments, using digital simulators, such as PhET, which allowed students to visualize and adjust the parameters of the satellite launch simulations.

An important part of the didactic sequence was the use of digital simulators, such as PhET, which allowed students to virtually experience the launch of satellites and the operation of GPS. In addition, Google Maps has been integrated into the process to show the application of real-time GPS, highlighting how the concepts of satellite trilateration and triangulation are used to determine the position of objects on the Earth's surface.

The students were challenged to solve problems and make decisions throughout the didactic sequence. The RPG's narrative imposed situations in which teams needed to calculate launch parameters, adjust trajectories, and correct any failures in satellite communication.

These challenges involved the practical application of the theoretical concepts learned in the classroom. For example, students needed to calculate the escape velocity needed for the satellite to reach the correct orbit and use equations of motion to predict the behavior of projectiles (satellites) in space.

At the end of the didactic sequence, there was an evaluation, in which the students reflected on the challenges faced and the solutions found. The evaluation included:

Feedback among students: students discussed in a group what worked or did not work during the activities, promoting a collaborative reflection on the learning process.

Testimonials: the students reported their experiences during the mission, emphasizing how much the use of RPG and gamification contributed to increase their motivation and interest in the concepts of Physics.

DATA COLLECTION AND ANALYSIS

Data collection and analysis were carried out in a structured way, with the objective of evaluating the impact of the didactic sequence on students' learning, their cognitive development and the perception of the use of gamification and RPG in the teaching of Physics. The data collection and analysis process as described in the work is detailed below.

Data collection was carried out during the implementation of the didactic sequence. Multiple methods were used to ensure that different aspects of the teaching-learning process were captured, focusing on both the students' cognitive performance and their qualitative perceptions of the method.

During the activities of the Ultra Secret Aerospace Mission (M.A.U.S.), the researcher acted as an observer and recorded the students' behaviors, their interaction with colleagues and with the tools used, in addition to the level of engagement in the activities. These observations were noted throughout the different stages of the didactic sequence, in order to evaluate how the students reacted to the gamification and role-playing activities, as well as their efforts to solve practical problems related to the concepts of Physics.

At the end of the didactic sequence, the students answered questionnaires designed to collect data on their perceptions and experiences with the use of gamification and RPG. The questionnaires included open and closed questions, covering topics such as: Level of interest in the topics covered before and after the sequence; Perceived difficulty in relation to the physical concepts worked on (such as gravitation and satellite movement); Engagement in role-playing and gamification activities; and Perception of teamwork and the use of digital technologies (simulators and Google Maps).

These questionnaires helped to understand how students evaluated the learning experience and whether there was a change in their attitudes towards Physics and the use of technologies in teaching.

To evaluate the impact of the didactic sequence on the cognitive development of the students, evaluation instruments were used before and after the application of the activities. This included the application of tests related to the physical concepts covered, such as the launch of satellites, parabolic movement and electromagnetic waves. The test results provided a quantitative basis for measuring students' progress in terms of conceptual understanding.

The performance tests were applied before and after the implementation of the didactic sequence to evaluate the students' evolution in understanding the physical concepts addressed, such as the launch of satellites and the operation of GPS. These tests were focused on questions that measured students' conceptual understanding in topics such as: Universal gravitation: calculation of the gravitational force and the understanding of how it affects the movement of satellites; Parabolic movement: evaluation of students' ability to solve problems of trajectory and speed of moving satellites; and Electromagnetic

Revista ARACÊ
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waves and GPS: understanding how waves are used to transmit location data in the GPS system.

The tests aimed to verify whether the students were able to apply the theoretical concepts in a practical way after participating in the gamified activities and the role-playing game.

At the end of the didactic sequence, the students answered perception questionnaires that included open and closed questions. These questionnaires were created to collect information about students' perceptions and experiences with the innovative methodology. The main topics evaluated in the questionnaires were: level of interest in the concepts of Physics before and after the didactic sequence; perceived difficulty in relation to the physical concepts addressed, such as gravitation and satellite movement; engagement in gamification and role-playing activities, asking if students felt more motivated to participate in classes and interact with colleagues; and perception of teamwork and the use of digital technologies (simulators and Google Maps).

During the application of the didactic sequence, the teacher acted as an observer, recording the behavior of the students, their interaction with colleagues and the level of engagement in the activities. The observations were noted throughout the different stages of the didactic sequence, focusing on: The active participation of students in the proposed activities; the ability of students to solve problems and collaborate as a team; and the students' reaction to the challenges and missions proposed during the RPG, including the degree of autonomy and protagonism demonstrated. These observations complemented the questionnaires and provided a practical and ongoing view of student engagement during the sequence.

At the end of the didactic sequence, an evaluation was carried out, in which the students reflected on the activities developed and discussed in a group what worked or not. This evaluation included: Feedback among students: Students discussed their perceptions of the teams' performance, identifying the challenges and solutions found throughout the process; Testimonials: The students shared their experiences on how role-playing and gamification contributed to the increase in interest in Physics concepts.

Assessment played an important role in promoting collaborative reflection and self-assessment, allowing students to understand their own learning process and actively engage in reviewing their efforts.

After data collection, the analysis of the results was done quantitatively and qualitatively: Quantitative: The data from the tests were statistically analyzed to compare the evolution of the students before and after the sequence. This comparison included the analysis of errors and successes in problems related to gravitation, motion and GPS; Qualitative: The answers to the questionnaires and the observations in the classroom were categorized to identify patterns of perception of the students in relation to the applied methodology. Categories such as motivation, engagement and perception of difficulties were created, which helped to identify the acceptance of the methodology by the students.

The results of the performance tests were compared before and after the implementation of the didactic sequence. This analysis was done to verify how much the sequence influenced the understanding of the concepts of Physics. The following were considered: The number of errors made before and after the application of the sequence; The evolution of students in relation to the ability to solve specific problems, such as the calculation of satellite trajectories and the use of the concepts of gravity and motion.

These data were statistically analyzed, using basic techniques of comparison of means, to evaluate the direct impact of the didactic sequence on the cognitive performance of the students.

The qualitative analysis was conducted based on questionnaires and classroom observations. The answers to the questionnaires were categorized and analyzed to identify patterns in the students' perceptions. Categories were created, such as: Motivation: how motivated students felt to learn Physics with the gamified approach; Engagement: the willingness of students to participate in activities and collaborate with colleagues; and Perception of difficulties: how the students evaluated the difficulty of the concepts after the application of the didactic sequence and felt that the methodology facilitated learning.

The classroom observations also provided qualitative data on the students' behavior during the activities, allowing the analysis of factors such as collaboration, active participation and the confidence demonstrated during the execution of the tasks. From this, the strengths and weaknesses of the applied methodology were identified, as well as the degree of acceptance of students in relation to the use of simulators and digital tools in teaching.

RESULTS AND DISCUSSIONS

The main results observed during the application of the didactic sequence based on gamification and RPG showed a significant impact on the cognitive development of students, as well as on their motivation and engagement with the learning of Physics concepts.

The tests carried out before and after the application of the didactic sequence indicated a substantial improvement in the understanding of the physical concepts related to the launch of satellites and the operation of GPS. This demonstrates that the innovative methodology, which integrated gamification and RPG, was effective in facilitating the fixation of complex content, especially those related to gravitation and parabolic movement.

One of the most notable effects was the increase in student engagement during activities. The active participation of the students in the activities, the interaction between them and the motivation to solve the problems related to the space mission were significantly amplified by the playful and collaborative approach of the sequence.

Students' motivation also increased noticeably, as students reported that the gamified format made Physics content more attractive and accessible, breaking the initial barrier of disinterest common in theoretical concept classes. The following is the final report of two of the students,

Student identified as A-27, report 1:

> "Since the beginning of the year, these 4 classes have been the ones I liked the most, and I think they were the ones I interacted with the most as well. The missions were very cool, the way the teacher digitized the missions was cool, the way he explained and interacted with us was very cool. I had never tried to know about satellites and in these classes I even learned how a rocket launches a satellite, I found out that the first satellite launched into space is called SPUTNIK. And it was in these classes that I was able to understand and learn about the formulas, I learned how to assemble and solve the accounts. In these classes my class became a G.I.S (secret intelligence group) each student became a scientist officer each with a codename, mine was tcr-27, and now we were on an Ultra Secret Aerospace Mission, with the objective of developing and sending a new satellite into space. I forgot to mention that the name of the 3°A class on this mission became SPUTNIK in honor of the first satellite sent into space. I liked all 4 missions, but number 4: simulation of rocket launches using PHET was the one I liked the most, and in this one we had to hit a 20.0m target with a "cannon" we measured the mass, diameter, gravity, air resistance and altitude we had to change all this to hit the target but as this was practical it was very interesting. (Survey Data, 2022)".

Student identified as A-22, report 2:

> "In the class on 09/22, Thursday, we had very didactic classes given by Professor Luís. The activity basically consisted of an RPG, where students were part of a secret intelligence group (G.I.S). The exercise was divided into parts, 4 missions. The first of

Revista ARACÊ
ISSN: 2358-2472

> them was to create a code name for "times of war", we should also fill in our locality, which could not be the city of Curitiba-PR or Pitanga-PR. In sequence, in mission 2, the students (scientist officers) had the task of discovering the gravitational force and also the value of the mass of the earth M. A and the mass of the satellite m, we adopted the individual call number and the R we used research sites, in mission 3, we had to find the drag force that is represented by the letter W. After performing all the proposed exercises we prepared for the simulations that will happen in the sequence and review the correct completion of the operations card. It is essential that everything is correct so far. On the last mission, we had a very dynamic task using a rocket launch simulation application, the goal was to reach the target by filling in the data with what we already had and changing only the mass. Speaking from personal experience, it was a fun class that held our attention and made us more interested in the content. I wish we had more classes of this style. (Survey Data, 2022)".

A highlight was the teamwork, as the RPG activity required a strong collaboration between the students, since each one played a specific role in the aerospace mission. The ability to work in groups was well evaluated by the students themselves, and the level of collaboration increased, according to the observations in the classroom and the answers to the questionnaires.

Another aspect to be considered concerns the limitation of access to technologies in a public school, which is one of the main challenges during the application of the didactic sequence based on gamification and RPG. This limitation mainly affected the use of digital simulators and other technological tools, essential for the complete implementation of the planned activities.

Because the study was conducted in a public school with limited resources, there were difficulties in accessing appropriate technological devices, such as computers and devices with a high-quality internet connection. The lack of adequate infrastructure, common in many public schools in Brazil, limited the full use of technologies such as: Physics simulators, such as PhET, which would be used to help students visualize and experience the launch of satellites and the operation of GPS; Online tools, such as Google Maps, that would allow a practical application of the GPS system.

Due to these limitations, the use of technologies had to be adapted according to the availability of resources. At times, the planned simulations had to be simplified or adjusted to the time available and the technological capacity of the school. This required the use of alternative methodologies or the demonstration of simulations because there are few devices for the entire class.

The lack of access to technologies affected student engagement at times, since an important part of the pedagogical proposal depended on practical interaction with digital tools. This limitation also represented an obstacle to the full exploration of the didactic

Revista ARACÊ
ISSN: 2358-2472

sequence, as it prevented students from being able to fully test their hypotheses and manipulate variables in simulators autonomously and individually.

These limitations are common in Brazilian public schools, highlighting the need for greater investment in technological infrastructure so that active and innovative methodologies, such as gamification and RPG, can be applied more effectively. In addition, the study suggests that public schools, in particular, need adaptation strategies to implement these methodologies in environments with technological constraints, including the use of low-cost technologies or the sharing of resources.

CONCLUSION

By carrying out the work reported here, it was concluded that the methodology based on gamification and Role Playing Game (RPG) was highly effective for teaching Physics concepts related to the launch of satellites and the Global Positioning System (GPS).

The application of this methodology resulted in a significant increase in student engagement and motivation, as well as a substantial improvement in the understanding of physical concepts. The collaborative and immersive approach, with the use of digital tools and simulations, allowed students to apply theoretical concepts in a practical and interactive way, making the learning process more meaningful and accessible.

The gamified methodology and RPG proved effective for: actively engaging students in classroom activities, promoting more dynamic learning; facilitate the understanding of abstract concepts, such as gravitation and parabolic motion, through practical activities; and to stimulate teamwork, developing social and collaborative skills, essential in the teaching-learning process.

The proposed didactic sequence can be adapted and replicated in various educational contexts, especially in other disciplines that involve abstract concepts or that can be contextualized with the use of simulations and digital tools. The methodology is particularly promising in schools that seek to integrate educational technologies and active methodologies into the curriculum, promoting the development of competencies that go beyond technical content, such as critical thinking, problem-solving, and collaboration.

The study has important practical implications for education: pedagogical innovation: gamification and role-playing offer alternatives to traditional methodologies, creating a more inclusive and engaging learning environment; integration of technologies: the use of simulators and tools such as Google Maps proved to be effective in teaching Physics

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concepts, suggesting that other disciplines can benefit from similar digital resources; and skills development: the methodology not only promoted conceptual understanding, but also developed socio-emotional skills, such as communication and teamwork.

Future research could explore: the application of the methodology in different areas of knowledge, investigating its effectiveness in disciplines such as Chemistry, Biology and Mathematics; long-term studies to assess the ongoing impact of gamification and role-playing on students' academic performance and cognitive development; and the influence of different technological tools on the learning process, investigating how the combination of simulators, augmented reality and other emerging technologies can optimize teaching.

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