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Remote teaching and gamification: Use of the PhET Simulator in chemistry teaching

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ABSTRACT
This article focuses on the use of the PhET Simulator, during Remote Teaching, as a learning strategy in the gamification of Chemistry teaching. Due to the COVID-19 scenario and the students' difficulty in apprehending content related to the Periodic Table, the use of this Simulator was proposed and is justified by the interactivity between 47 students from the 9th grade of Elementary School. This is a quantitative-qualitative action research and the main objective was to show that remote work combined with gamification enabled the development of socio-emotional skills and skills related to the context of Chemistry using the Simulator as a playful and motivating tool.

Keywords: Gamification, PhET Simulator, Chemistry Teaching.

1 INTRODUCTION

The present work has as its theme the use of the *PhET* Simulator through Remote Teaching, as a significant learning strategy in the gamification of Chemistry teaching for students in the 9th year of Elementary School.

The challenges faced in the context of Remote Teaching, due to the COVID-19 scenario and the difficulty of students in apprehending content related to the Periodic Table are problems experienced in the daily life of Chemistry classes. Thus, the following question is asked: is it possible to engage students in this context through the use of the *PhET Simulator* combined with online gamification during remote classes in the Chemistry discipline?

In view of this problem, the work is justified by involving students in the teaching and learning process through interactivity, engagement and, consequently, in the expectation of positive results during remote teaching.

Therefore, the general objective of the work is to promote interaction and improvement of teaching, with the use of the PhET *Simulator* through Remote Teaching, as a significant learning strategy in the gamification of Chemistry teaching. The specific objectives are: to use the *PhET Simulator* as a gamification strategy for the teaching of Chemistry; to know the Periodic Table in a playful way, in order to facilitate the knowledge of the Structure of Matter and to engage the student in the teaching and learning process remotely, evidencing a significant improvement in the teaching and learning of Chemistry.

According to the State Department of Education - SEE-SP, it is essential that the teacher mediates "in the teaching and learning process in order to contribute to the formation of critical, reflective, autonomous and transformative students", promoting "an integral formation of students" (SÃO PAULO, 2019, p. 416).

Thus, it is crucial to "appropriate new methodological paths for a more dynamic, creative and interesting teaching-learning process", which justifies the use of several active methodologies of knowledge, including gamification as a possibility of improving disciplines (SÃO PAULO, 2019, p. 416).

In this context, bringing conceptual knowledge in Natural Sciences and its Technologies is essential for the improvement of student learning, considering that this knowledge has been improved, becoming relevant to the teaching of Chemistry in Elementary School, in order to propose a detailed study on the various themes, including Matter and Energy. These themes allow students a greater sense of investigation, analysis, and discussion of problem situations that arise in the face of diverse sociocultural contexts (BRASIL, 2017).

Next, the theoretical foundation, methodology, results and discussion and final considerations will be presented.

2 METHODOLOGY

The research is based on a scientific investigation with 47 9th grade students from a school located in a municipality in the state of Rio de Janeiro. According to Gil (2008), a quantitative-qualitative action research will be carried out from an initial investigation on subjects related to the Periodic Table in order to investigate the level of knowledge of students in relation to the proposed theme, remote classes for knowledge of the subject, interaction through the *PhET* Simulator and a final questionnaire to verify the effectiveness of the gamification strategy applied to the teaching and learning process.

Thus, a total of 6 remote classes through *Microsoft Teams* were required to apply this methodology. In the first two classes, the Chemistry teacher presented the Project, inserted the student within the context of the theme addressed and applied the Diagnostic Test, as presented in Chart 1.

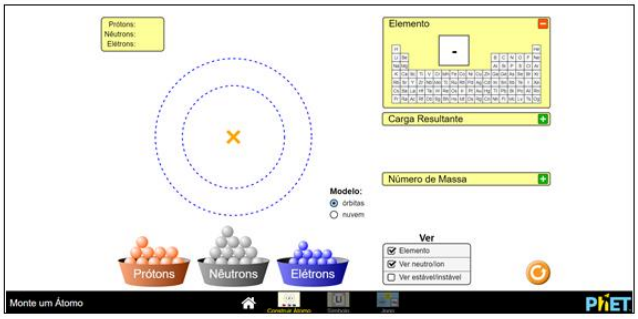
Table 1: Diagnostic Evaluation – Questionnaire 1.

1 - What are the subdivisions of an atom? A) prótons, eletrons, cátions. B) protons, electrons, neutrons C) cations, isotopes, neutrons. D) ions, isotones, protons.
The atom is the smallest particle that identifies a chemical element. It has two parts, namely: one of them is the nucleus, made up of protons and neutrons, and the other is the outer region – the electrosphere – through which electrons circulate. Some experiments have made it possible to discover the characteristics of the constituent particles of the atom. Regarding these characteristics, indicate the correct alternative. A) Protons and electrons have equal masses and electric charges of opposite signs. B) Among the atomic particles, electrons have the greatest mass and occupy the greatest volume in the atom. C) Among atomic particles, protons and neutrons have the greatest mass and occupy the greatest volume in the atom. D) Among atomic particles, protons and neutrons have more mass, but occupy a very small volume relative to the total volume of the atom.
3 - The O^{2-} oxide ion has the same number of electrons as: Data: O (Z=8); F (Z=9); Na (Z=11); Ca (Z=20); S (Z=16); A) The fluoride ion F^{-} B) the sodium atom Na. C) o pure cálcio Ca^{2+} (a) The S.A.S.
An atom is made up of 28 electrons and has a mass number of 50. Check the box that shows your atomic number and neutron number, respectively. A) 26 and 24 B) 28 and 50 C) 28 and 22 D) 19 and 40

Source: BRASIL ESCOLA, (2020); WORLD EDUCATION, (2020).

Then, two classes were held to give *feedback* in relation to the Diagnostic Evaluation, correction of the exercises and explanation regarding the main errors that occurred. After clearing all doubts, in the last two classes, the teacher presented the *PhET* simulator gamifying the Chemistry class, seeking to make it more attractive and interactive, enabling an individual and team online game. Figure 1 shows images of the game used during the interaction.

Figure 1: PhET *Simulator* – Gamifying the Chemistry class



Fonte: https://phet.colorado.edu/pt_BR/simulation/build-an-atom

At the end, a Final Evaluation (Chart 2) was applied in *Google Forms* in order to verify how significant the learning was.

Table 2: Final Evaluation.

In the late eighteenth and early nineteenth centuries, atomic models evolved greatly. Currently, the most studied subdivision of an atom is: A) Nucleus (protons, electrons and cations) B) Electrosphere (protons, electrons and neutrons) C) Electrosphere (electrons) and Nucleus (protons and neutrons) D) Nucleus (protons and electrons) and Electrosphere (neutrons)
2- We study that matter is everything that has mass and occupies a place in space. We also study that all matter is made up of atoms. The atom is the smallest particle that identifies a chemical element. It has two parts, namely: one of them is the nucleus, made up of protons and neutrons, and the other is the outer region – the electrosphere – through which electrons circulate. Some experiments have made it possible to discover the characteristics of the constituent particles of the atom. A) Protons orbit around the nucleus of the atom. B) the nucleus, because it has practically all the mass of the atom, is also responsible for the largest volume. C) among atomic particles, protons are responsible for the identity of the atom, that is, the number of protons in the nucleus of an atom is what determines which chemical element it belongs to. D) Among the atomic particles, protons and neutrons sound the smallest mass within an atom and therefore occupy a very small volume in relation to the total volume of the atom.
3- We study that atoms are particles in which the number of electrons is equal to the number of protons and that, when the atom gains or loses electrons, it is called an ion. Does the aluminum ion Al^{+3} have the same number of electrons as? [Exercise data: O (Z=8); F (Z=9); Ne (Z=10); Na (Z=11); mg (Z=12); Al (Z=13); S (Z=16);] A) The neon atom: Ne B) Fluorine atom: F C) Sodium atom: Na D) The sulfide s ion $^{-2}$
An atom is made up of 13 electrons and has a mass number of 27. Check the box that shows your atomic number and neutron number, respectively. A) 13 and 27 B) 13 and 14 C) 13 and 13 D) 27 and 13

Source: BRASIL ESCOLA, (2020); WORLD EDUCATION, (2020).

Then, a feedback was given *on the Final Evaluation and, soon after, the teacher made available a Project Evaluation Questionnaire, elaborated* in Google Forms *(Chart 3) in order to obtain* feedback *from the students on how much this active learning strategy motivated them, with regard to socio-emotional learning skills.*

Chart 3: How was my experience in the Chemistry Project?

1- Did the use of the *Phet Simulator* facilitate the understanding of the activities related to the Periodic Table? a) yes, it helped a lot b) yes, it helped a bit c) yes, but it just reinforced what I already know/what I can do d) no, it didn't help
2- Did the online interaction during the Phet Simulator game facilitate communication and understanding of the theme, especially because it was carried out in a team simultaneously? a) yes, it helped a lot b) yes, it helped a bit c) yes, but it just reinforced what I already know/what I can do d) no, it didn't help
3- Did participating in remote Chemistry classes involving the use of the *Phet* Simulator help make the class more attractive, interactive and meaningful? a) yes, it helped a lot b) yes, it helped a bit c) yes, but it just reinforced what I already know/what I can do d) no, it didn't help
4) How was your experience during the project? What did you learn over the course of the proposal? R:

Source: Prepared by the authors.

3 LITERATURE REVIEW

In the context experienced by Brazil and the world, due to the COVID-19 scenario, schools have sought ways to adapt to fully remote teaching. The teaching and learning process has become a challenge for both the teacher and the student. Thus, adding to the process the use of the *PhET* Simulator combined with the gamification of Chemistry teaching was essential to provide meaningful teaching through virtual learning environments.

In this way, meaningful learning occurs through the variety of possibilities of access to the various networks, combinations of ideas, exchanges of experiences and syntheses combined with access to digital media. In this sense, the school has the function of enabling the student to make sense of things, understanding them and contextualizing them under a critical, broad and life-related look (BACICH et al. 2015).

Therefore, using simulators as educational tools in the teaching and learning process is to insert the student in the digital age in virtual learning environments, making classes more attractive, playful and motivating (BARÃO, 2006; ROMEIRO et al., 2021; ALVES et al., 2019).

According to Valente (2001), knowledge is apprehended as the student relates to subjects that he or she has already mastered and the inclusion of new concepts in order to build knowledge continuously through interactive simulators in digital media. The interactions through the simulations are proportional in a playful, interactive and intuitive way, making the student learn, build and acquire new concepts and information.

Thus, digital media have become a crucial tool for the improvement of the teaching and learning process and, especially, by gamifying the teaching of Chemistry through virtual simulators, as it enables different ways of learning the proposed content.

From this perspective, Martins and Giraffa (2015) ensure that students become more motivated and engaged in this process when faced with the proposal to use gamification, a word from the English language gamification, so that learning is more meaningful. The authors also mention that gamifying teaching has become something recurrent in the educational field as a pedagogical methodology, making the learning proposal playful, attractive and motivating.

In view of this, France *et. al.* (2019) points out that gamifying, using games as a motivational tool in the context of teaching and learning, aims to draw students' attention to decision-making, attitudes and problem solving in order to improve learning. Games stimulate thinking, challenge, mastery and control that are essential characteristics in the act of reflection, critical thinking and, at the same time, present instant *feedback* on the results to be achieved, promoting inspiration for new challenges proposed.

In this context, achieving goals and acquiring prizes during the stages of the game makes students more interested and motivated to continue the challenges. Therefore, the gamification strategy, in addition to teaching, encourages us to continue participating and interacting, ceasing to be a boring and unmotivated class, escaping from traditional teaching strategies (MCGONICAL, 2012).

In view of this strategy of gamifying teaching, the use of the PhET Simulator (Physics *Education Technology*) of the University of Colorado (USA) will be an important tool for the development and improvement of skills and abilities related to the teaching of Chemistry to students in the 9th grade of Elementary School, since the PhET project brings several interactive simulations for the teaching of Physics. Chemistry, Mathematics, Earth Sciences, and Biology. The platform provides several free simulators for educational use and can be used with or without an internet connection, facilitating the teaching and learning process (PHET, 2020).

Therefore, the use of virtual simulators as a technological pedagogical strategy is fundamental for remote learning, since it is opposed to the traditional teaching method and shows chemical and physical processes more easily and clearly, without the need for physical laboratories (COELHO, 2002).

In view of the applied methodology, both student and teacher will be engaged in the teaching and learning process, so that there is an active construction of knowledge. According to Freire (1996), "teaching is not only transferring knowledge, but providing possibilities for its construction".

Therefore, staying engaged in digital media makes the teacher not only a transmitter of knowledge but also a mediator of the teaching and learning process.

4 RESULTS AND DISCUSSION

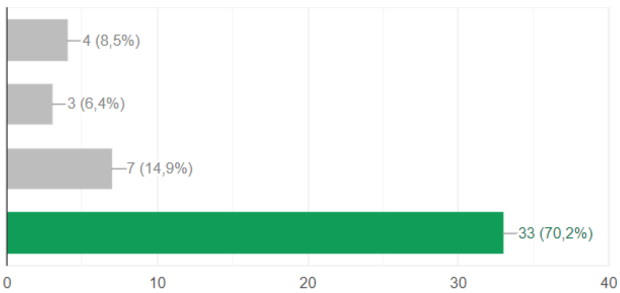
Both tests, Diagnostic Evaluation and Final Evaluation, were elaborated according to the BNCC's ability:

> (EF09CI03) Identify models that describe the structure of matter (constitution of the atom and composition of simple molecules) and recognize its historical evolution (BRASIL, 2017, p. 351).

4.1 RESULTS OF THE DIAGNOSTIC EVALUATION

Starting with the analysis of question 1 of the Diagnostic Assessment, in this one the students obtained 100% of correct answers, demonstrating in this specific case knowledge of the concept. Then, in relation to question 2 (Figure 2), it was noted that there was a good performance (70.2%) about the question that seeks to assess whether the student understood the characteristics of the constituent particles.

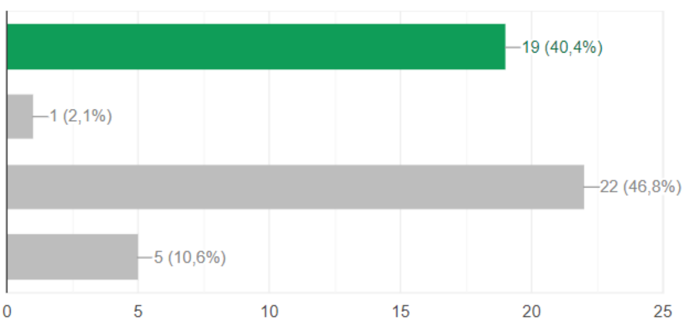
Figure 2: Question 2 - Diagnostic Evaluation.



Source: Prepared by the authors.

The previous results did not occur in the results of question 3 (Figure 3), in which only 40.4% of the students were able to correctly calculate the number of electrons of the O^{2-} oxide ion and compare it with the proposed alternatives.

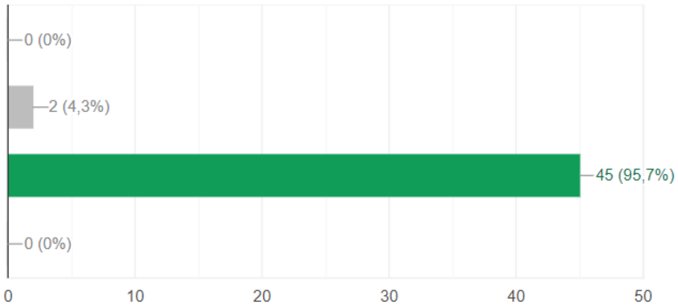
Figure 3: Question 3 - Diagnostic Evaluation.



Source: Prepared by the authors.

Finally, the yield was again expressive in question 4 (Figure 4) when the calculation of atomic and neutron numbers was requested.

Figure 4: Question 4 - Diagnostic Evaluation.



Source: Prepared by the authors.

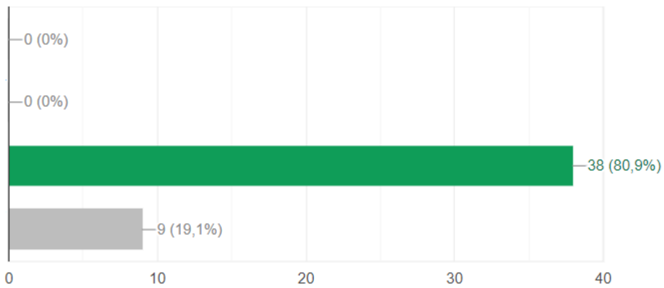
4.2 RESULTS OF THE FINAL EVALUATION

After online, individual and team interaction, the students answered an online assessment in order to verify whether the methodology used was satisfactory. The questions of the Final Evaluation were designed to be respectively similar to the questions of the Diagnostic Evaluation.

Thus, initially evaluating question 1 of the Final Evaluation, it was again noted a 100% success rate when the student was asked to demonstrate knowledge about subdivisions of an atom.

In the second question (Figure 5), 80.9% answered correctly the question about "Characteristics of the constituent particles", showing an improvement in relation to the Diagnostic Evaluation.

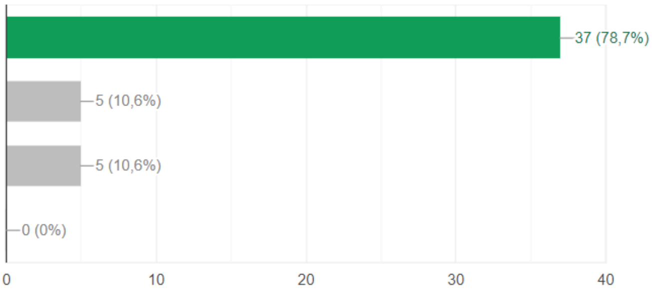
Figure 5: Question 2 - Final Evaluation.



Source: Prepared by the authors.

Regarding the third question (Figure 6), a total of 37 students (78.7%) were able to correctly sign the question, showing a satisfactory result in comparison with the Diagnostic Evaluation.

Figure 6: Question 3 - Final Evaluation.

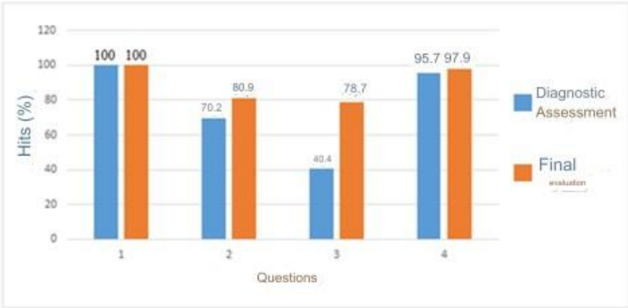


Source: Prepared by the authors.

Finally, in the last question, 97.9% (46 students) of the students showed efficiency in answering the question about "Atomic number and number of neutrons", demonstrating no difficulties in the subject.

When comparing the percentage between the Diagnostic Evaluation and the Final Evaluation, an improvement in the results can be seen, as shown in Figure 7.

Figure 7: Comparison between the Diagnostic Evaluation and the Final Evaluation.



Source: Prepared by the authors.

In other words, Figure 7 can show us that in concepts that we believed to be established, this was corroborated, and for concepts that were not well assimilated, these were reinforced.

4.3 RESULTS OF THE STUDENTS' SELF-ASSESSMENT ON THEIR PARTICIPATION IN THE PROJECT

After feedback on the positive result of the application of the project with the use of the *PhET simulator*, the students were able to answer a questionnaire prepared in *Google Forms*. This questionnaire was crucial for us to obtain feedback from the students about how the experience was in the Project, with regard to socio-emotional skills, considering interaction, teamwork and online learning as essential factors for the effectiveness of the teaching and learning process. Thus, it was possible to verify how much the students were involved and how was the experience during the execution of the proposed activities. Table 4 below shows the results of this self-assessment.

Through the answers, a satisfactory result is perceived, since most of the students answered alternatives A and B, which prove that the use of the *PhET* simulator, the online interaction and the ease of communication and understanding of the theme "helped a lot" in the engagement and "helped a little", respectively. On the other hand, no one pointed out alternative C, because it mentioned that the strategies helped, but only reinforced what they already knew. This shows that the students did not understand the subject and after the execution of the process, it proved to be effective in its proposal. Regarding answer D, a total of (8.5%) of the students said that the proposal did not help with understanding, interaction and engagement.

Table 4: Students' self-assessment.

	Responses in %			
Questions	The	B	C	D
1- Did the use of the *Phet Simulator* facilitate the understanding of the activities related to the Periodic Table?	74,5	17,0	0	8,5
2- Did the online interaction during the Phet Simulator game facilitate communication and understanding of the theme, especially because it was carried out in a team simultaneously?	70,2	21,3	0	8,5
3- Did participating in remote Chemistry classes involving the use of the *Phet* Simulator help make the class more attractive, interactive and meaningful?	68,1	23,4	0	8,5

Source: Survey information (2020).

4.4 MAIN IMPRESSIONS ON STUDENT FEEDBACK ON THE PROJECT

The last question of the self-assessment questionnaire was an open-ended question about "How was your experience during the project? What did you learn over the course of the proposal?" Among the main *feedbacks* , the following stand out:

> My experience with this project helped me a lot, especially in the material we are having now, I didn't expect that it would help me so much. The game is very interesting and very simple to understand and do the activities (Student 1).
>
> Thank God I was able to do most of the tasks, I really enjoyed the interaction with the PhET simulator (Student 2).
>
> It led me to understand more, but not so much, the practice with the whole class led to a good interaction and more interest (Student 3).
>
> I had a good experience, I learned a lot about chemistry, such as what protons, neutrons and electrons are, chemical bonds and electron distribution. The games during the class made it a little easier to understand the material. I had no difficulties in understanding the material and the exercises (Student 4).
>
> The proposal was very good. The game is really very interactive and has facilitated a better understanding of the subject, as it has become something more visible and practical. In addition to being fun and the exercises easy to understand (Student 5).
>
> I thought it was fantastic. Something that seemed difficult, after the game everything became easier (Student 6).

> I liked the dynamics. We were able to play, ask questions by playing and with the help of our teammates we could earn more stars in the game. Unwittingly, I learned about the subjects asked on the test. It helped me a lot (Student 7).
> My experience in the project was very good. I learned a lot of Chemistry by playing (Student 8).
>
> I learned that involving games and simulators in Chemistry classes greatly improves interest in the subject (Student 9).
>
> It made it much easier to learn Chemistry, in addition to being much easier and more fun (Student 10).
>
> It became easier to understand the subject by debating the subject with classmates and playing games (Student 11).
>
> The PhET simulator is very interesting, playing, playing and learning was very cool, especially in the Chemistry classes (Student 12).
>
> Very good. I didn't know the PhET simulator, I saw that in addition to Chemistry subjects there are other interesting subjects. Very good initiative (Student 13).

In the face of so many positive responses, there are those who had negative impressions, as follows:

> I don't think it helped much (Student A).
>
> It didn't make it very easy for me to study by this method (Student B).

This shows that it will still be necessary to make changes in the process and improve the strategy, inserting new challenges to reach the public that did not have it easy or that the method did not help much, because despite being few students, the interaction and engagement of the entire team becomes essential.

5 FINAL THOUGHTS

The strategy used with 9th grade students was very efficient, since the students were able to make learning more interactive and meaningful through engagement, showing a positive social and cultural growth in the development of competencies and skills related to the year/grade discipline involved.

The use of the *PhET* Simulator as a significant learning strategy in the gamification of Chemistry teaching was fundamental in the teaching and learning process, as students felt more motivated and engaged.

It is also important to point out that remote work combined with the gamification of teaching enabled the development of socio-emotional skills, as well as skills related to the context of Chemistry in a playful way using the *PhET* Simulator as a motivating tool, promoting social and cultural growth of students.

The strategies used proved to be effective in view of the results, but we detected the need to insert new challenges to promote the total engagement of students, especially those who did not feel attracted and motivated.

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