

PhET simulations: didactic-pedagogical resource for science teaching aligned to the Common National Curricular Base

ABSTRACT

Science teaching is often developed through traditional methodological practices, which privilege the transposition of the content provided in the curriculum with only a conceptual, fragmented character, sometimes disconnected, which contributes to mechanical memorization and demotivation of the student. In this scenario, the teacher assumes a fundamental role in the search for alternatives that privilege meaningful learning, by actively promoting the formation of knowledge by the student, making the classes more attractive and less abstract as to the phenomenon related to the Natural Sciences. Thus, the development of this work aimed to analyze interactive simulations of the Physics Educational Technology (PhET) project at the University of Colorado, regarding the possibilities of employment as a didactic-pedagogical resource, for Sciences teaching in the final grades of elementary school. To develop this work, a survey of the number of available simulations, analyzes and systematizations was applied, regarding the thematic unit, objects of knowledge and skills in the light of the National Common Curricular Base. The 14 (fourteen) software selected and described in this compendium will serve as pedagogical support for the proposition of interactive activities, which actively promote the construction of scientific knowledge, through the use of digital tools, to the detriment of the accumulation of content in a systematic way.

KEYWORDS: Simulation software. Science Teaching. National Common Curricular Base.

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1 INTRODUCTION

The Natural Science teaching in Brazil is still marked by a conservative conception, based on the memorization of abstract and complex contents, which are often disconnected from the daily life and social reality of students, which makes teaching boring and contributes to demotivation and students' lack of interest in Science classes (LEITE *et al.*, 2017; SOCIEDADE BRASILEIRA PARA O PROGRESSO DA CIÊNCIA, 2012).

In this scenario, it is essential to give new meaning to the pedagogical practices adopted by teachers through the search and/or development of different methodological strategies that favor the use of varied didactic-pedagogical resources and changes in the approach to content, in order to provide the construction of scientific knowledge, in a generation of students increasingly connected to the digital world and who are hardly instigated in formal classes (BACICH; MORAN, 2018; NICOLA; PANIZ, 2016).

Therefore, this investigation aims to identify, analyze, systematize and describe simulator software in the light of the National Common Curriculum Base (BNCC), so that they can be used as a didactic-pedagogical resource in the final years of elementary school, combining technology and active learning .

In this paper, the simulation software PhET (Physics Education Technology), developed by the University of Colorado, in Boulder, will be focused. The research happens due to the fact that the use of simulator software has been gaining ground in the teaching-learning process, for challenging, engaging and motivating a generation of digital native students and for enabling teachers to work concretely with abstract concepts, create models, present phenomena, reproduce experiments without the need for a laboratory in face-to-face and remote teaching, and contextualize the daily life of the student in an illustrated and playful way (FERREIRA; PEREIRA; SOUSA, 2019; GREGÓRIO; OLIVEIRA; MATOS, 2016; RAMOS; CARDOSO; CARVALHO , 2020; SANTOS; FREITAS; LOPES, 2020; SARTORE, 2019).

2 PhET SIMULATIONS

The interactive simulations project PhET makes available several simulations free of charge (https://phet.colorado.edu/pt_BR/), in Java, Flash or HTML5 format, which require attribution of the work. Conceptual or operational simulations are distributed by knowledge area (Physics, Chemistry, Mathematics, Earth Sciences and Biology) and can be copied or performed online on electronic devices (computer, tablet or cell phone) (PhET, 2021).

Currently, the platform offers 105 (one hundred and five) simulations in Physics, 53 (fifty-three) simulations in Chemistry, which are divided into General and Quantum Chemistry, 43 (forty-three) simulations in Mathematics, 25 (twenty-five) simulations of Earth Sciences and 19 (nineteen) Biology simulations. All have descriptions in the section on and described learning objectives (PhET, 2021).

Furthermore, the platform also provides tips and activities submitted by teachers, in the section for teachers, and compatibility with operating systems and electronic devices, in the section requirements for programs (PhET, 2021).

3 METHODS

The present work is characterized as a qualitative research, classified as exploratory and descriptive, which presents a survey of the amount of available simulations, analyzes and systematizations in the light of the BNCC, regarding the employment possibilities for the construction of scientific knowledge in the years end of elementary school.

The research is based, mainly, on specific competence six of Natural Sciences for elementary education, which highlights the need to:

Use different languages and digital information and communication technologies to communicate, access and disseminate information, produce knowledge and solve problems of Natural Sciences in a critical, meaningful, reflective and ethical way (BRASIL, 2018, p. 324).

The analysis of 19 (nineteen) Biology simulations, (25) twenty-five Earth Science simulations, (53) fifty-three Chemistry simulations and (105) one hundred and five Physics simulations, available on the PhET website, were analyzed. (https://phet.colorado.edu/pt_BR/).

The simulations were selected, analyzed and systematized according to the three thematic units of the Natural Sciences area (Matter and energy, Life and evolution, Earth and universe), objects of knowledge and skills, defined in the BNCC. They were also described, regarding the possibility of application and learning objectives, in order to form a compendium that helps teachers in proposing interactive activities that provide scientific knowledge, through the use of digital tools.

4 RESULTS AND DISCUSSION

From the analysis of 202 (two hundred and two) simulation softwares in Biology, Earth Sciences, Chemistry and Physics, available on the PhET website (https://phet.colorado.edu/pt_BR/), 14 (fourteen) softwares were selected because they fit the thematic units, knowledge objects and skills recommended by the new BNCC.

The simulations were classified according to the BNCC curriculum organization in the thematic units Matter and energy, Life and evolution, Earth and universe. Among the software cataloged in this research, 11 (eleven) apply to the thematic unit Matter and energy (Chart 1), 2 (two) apply to the thematic unit Earth and universe (Chart 2) and 1 (one) applies to the thematic unit Life and evolution (Chart 3). Such data reflect the large amount of software developed for teaching Chemistry and Physics, which are included in the Matter and Energy unit, given the reduced number of software that address living beings (characteristics, evolution and interactions with other beings and the environment), included in the Life and Evolution unit.

Chart 1 - Software cataloged regarding the possibility of employment as a didactic-pedagogical resource in the subject Matter and energy unit

MATTER AND ENERGY THEMATIC UNIT		
INTERACTIVE SIMULATION (PhET)	OBJECTS OF KNOWLEDGE (BNCC)	SKILLS (BNCC)
Salts and solubility	6th grade: Homogeneous and heterogeneous mixtures	(EF06CI01) Classify as homogeneous or heterogeneous a mixture of two or more materials (water and salt, water and oil, water and sand, etc.).
Energy forms and changes	8th grade: Sources and Types of Energy Energy changes	(EF08CI01) Identify and classify different sources (renewable and non-renewable) and types of energy used in residences, communities or cities.
Kit to assemble a DC circuit	8th grade: Electric circuits	(EF08CI02) Build electrical circuits with batteries, wires and lamp, or other devices, and compare them to residential electrical circuits.
States of matter: basic	9th grade: Matter structure	(EF09CI01) Investigate changes in the physical state of matter and explain these changes based on the submicroscopic constitution model.
Reagents, products and excess	9th grade: Quantitative aspects of chemical changes.	(EF09CI02) Compare quantities of reagents and products involved in chemical changes, establishing the proportion between their masses.
Hydrogen atom models	9th grade: Matter structure	(EF09CI03) Identify models that describe the structure of matter (constitution of the atom and composition of simple molecules) and recognize its historical evolution.
Molecular geometry: basic		
Color vision	9th grade: Matter structure	(EF09CI04) Plan and carry out experiments that show that all colors of light can be formed by composing the three primary colors of light, and that the color of an object is also related to the color of light that illuminates it.
Alfa decay	9th grade: Radiation and its applications in health	(EF09CI06) Classifying electromagnetic radiation by its frequencies, sources and applications, discussing and evaluating the implications of its use in remote control, cell phone, X-ray, microwave oven, photocells etc.
Beta decay		
Microwaves		

Source: The Author (2021).

As for the objects of knowledge, organized according to the years of elementary school (6th to 9th), the software can be used throughout elementary school, but mostly apply to the 9th grade, as we can see in the throughout Charts 1, 2 and 3.

Chart 2 – Software cataloged regarding the possibility of employment as a didactic-pedagogical resource in the thematic unit Earth and Universe

EARTH AND THE UNIVERSE THEMATIC UNITY		
INTERACTIVE SIMULATION (PhET)	SUBJECTS OF KNOWLEDGE (BNCC)	SKILLS (BNCC)
The greenhouse effect	7th grade: Greenhouse effect	(EF07CI13) Describe the natural mechanism of the greenhouse effect, its fundamental role in the development of life on Earth. Discuss the human actions responsible for their artificial increase (burning of fossil fuels, deforestation, fires etc.) and select and implement proposals for reversing or controlling this situation.
Tectonic plates	7th grade: Natural phenomena (volcanoes, earthquakes and tsunamis) Plate tectonics and continental drift	(EF07CI15) Interpret natural phenomena (such as volcanoes, earthquakes and tsunamis) and justify the rare occurrence of these phenomena in Brazil, based on the model of tectonic plates.

Source: The Author (2021).

Chart 3 – Software cataloged as to the possibility of employment as a didactic-pedagogical resource in the thematic unit Life and Evolution

LIFE AND EVOLUTION THEMATIC UNIT		
INTERACTIVE SIMULATION (PhET)	SUBJECTS OF KNOWLEDGE (BNCC)	HABILITIES (BNCC)
Natural selection	9th grade: evolutionary ideas	(EF09CI11) Discuss the evolution and diversity of species, based on the role of natural selection on the variants of the same species, resulting from the reproductive process.

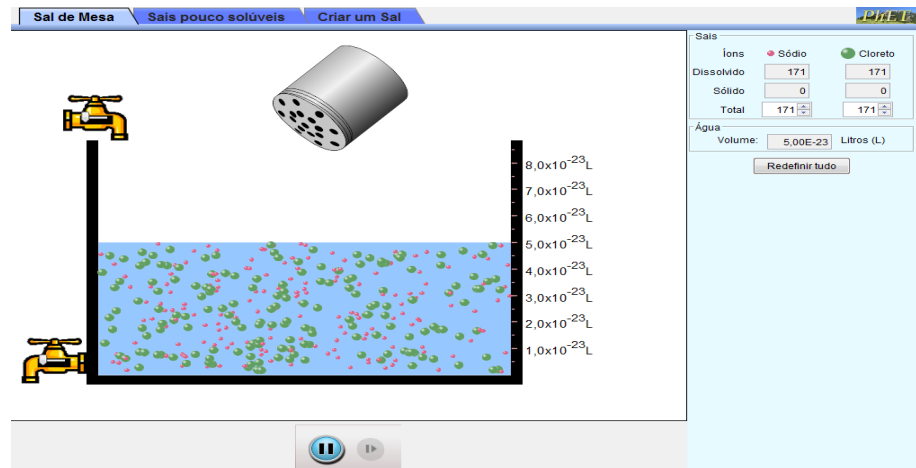
Source: The Author (2021).

This work selects and suggests the use of PhET simulation software as a didactic-pedagogical resource for covering all thematic units of the Natural Sciences, throughout the final grades of elementary school (6th to 9th), as well as for presenting great robustness and portability, which allows manipulation on various computers, with Windows, Linux, Chrome OS or MacOs operating systems and on electronic devices with Android and MacOs systems, without the need for internet or license, with a friendly interface, with mostly intuitive commands and exquisite visual, which allows interactivity with the learning object (PhET, 2021; REATEGUI & FINCO, 2010). Therefore, it follows, in detail, the learning goals of each simulation indicated.

4.1 Salts e solubility

This simulation can be adapted for use in elementary school and allows the student to add different salts to the water. Afterwards, observe the dissolution and formation of a homogeneous mixture, until the solution saturates, forming solid precipitates and a heterogeneous mixture (Figure 1).

Figure 1 – Visual representation of the simulation of salts and solubility



Source: PhET (2021).

The original learning goals are to list the solubility of different salts in order; calculate the molarity of the solution; measure the ratio of anions and cations (PhET, 2021). Contemplating BNCC skill EF06CI01 (BRASIL, 2018).

4.2 Forms of energy and changes

This work provides the observation of energy transfer when heating or cooling objects, embracing exploratory possibilities of basic energy concepts, through examples from the student's daily life (Figure 2).

Figure 2 – Visual representation of simulation - energy forms and changes



Source: PhET (2021).

The original learning goals are to predict how energy flows when heating or cooling objects; demonstrate energy conservation and how it can be changed, using everyday systems that align with BNCC's EF08CI01 ability (PhET, 2021; BRAZIL, 2018).

4.3 Kit for assembling a dc circuit

The virtual experience allows you to build their own circuit. In addition to determining which objects that are part of your daily life are insulators or conductors (Figure 3). This allows the teacher to explore basic concepts of electricity, while students take measurements and build their circuits, with lamps, batteries, among others, in a schematic or realistic diagram.

Figure 3 – Visual representation of the simulation - kit to assemble a DC circuit



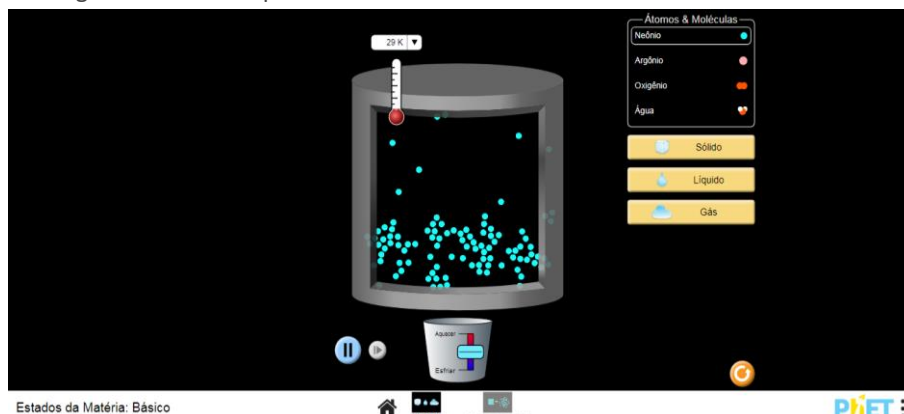
Source: PhET (2021).

The original learning goals are to explore basic concepts of electricity in circuits (series and parallel); understand measurements (ammeter and voltmeter); assimilate differences between conductive and insulating objects, similar to BNCC skill EF08CI02 (PhET, 2021; BRAZIL, 2018).

4.4 States of matter: Basic

The reproduction includes the visualization of the passage from one physical state to another, enabling the teacher to explore the behavior of particles according to temperature and pressure (Figure 4).

Figure 4 – Visual representation of the simulation of states of matter: basic



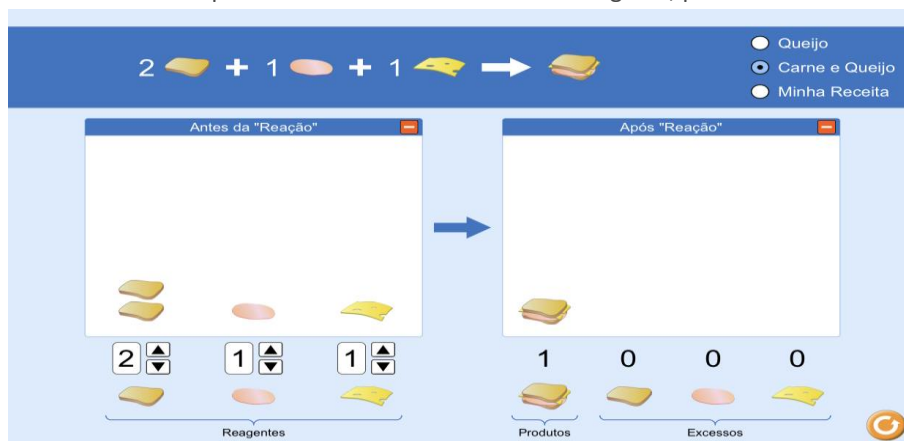
Source: PhET (2021).

The original learning objectives are to allow the visualization of the three physical states of matter (solid, liquid and gaseous); explain predictions of particle behavior according to temperature and pressure; capture the conduct of freezing and melting at the molecular level; understand the differences between the melting, freezing and boiling temperature of different substances, compatible with BNCC skill EF09CI01 (PhET, 2021; BRAZIL, 2018).

4.5 Reagents, products e excesses

The representation allows explaining chemical reactions through a game, in which students create their own sandwiches recognizing reagents, products and excesses, while choosing ingredients (Figure 5). Alternatively, students can also work with the molecular representation of matter.

Source 5 – Visual representation of the simulation of reagents, products and excesses



Source: PhET (2021).

The original learning goals are to recognize the conservation of atoms in a chemical reaction; identify reagents (limiting or not); point out products and excesses, quantities and proportions in a balanced chemical equation, a composition of BNCC ability EF09CI02 (PhET, 2021; BRAZIL, 2018).

4.6 Hydrogen atom models

The demonstration allows visualizing the hydrogen atom according to the models of Thomson, Rutherford-Bohr, Broglie and Schroedinger, providing opportunities for the teacher to explore aspects related to the construction of models (Figure 6).

Figure 6 – Visual representation of the simulation of hydrogen atom models



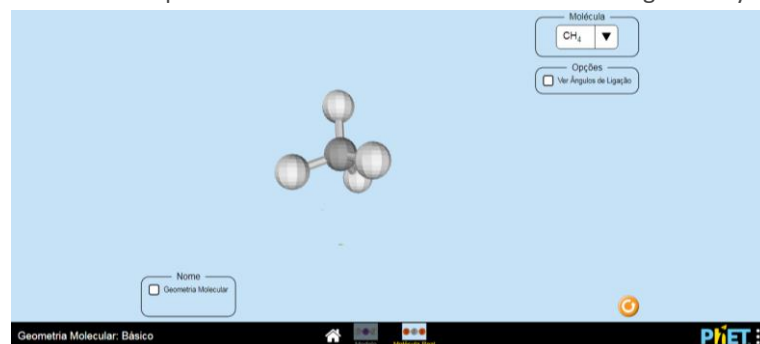
Source: PhET (2021).

The original learning goals are allowing the visualization of different atomic models; engage students in their construction; explain the experimental predictions and inadequacies of each historical model; relate the physical image of the orbits and the energy levels of an elétron, listed in BNCC skill EF09CI03 (PhET, 2021; BRAZIL, 2018).

4.7 Molecular geometry: Basic

This reconstitution allows the student to build molecules in 3D (Figure 7), with the objective of learning, to develop the ability to recognize that the shape of the molecule is due to the repulsion between atoms and that the bonds between them are not fixed, as in the skill EF09CI03 of the BNCC (PhET, 2021; BRAZIL, 2018).

Figure 7 – Visual representation of the simulation of molecular geometry: basic

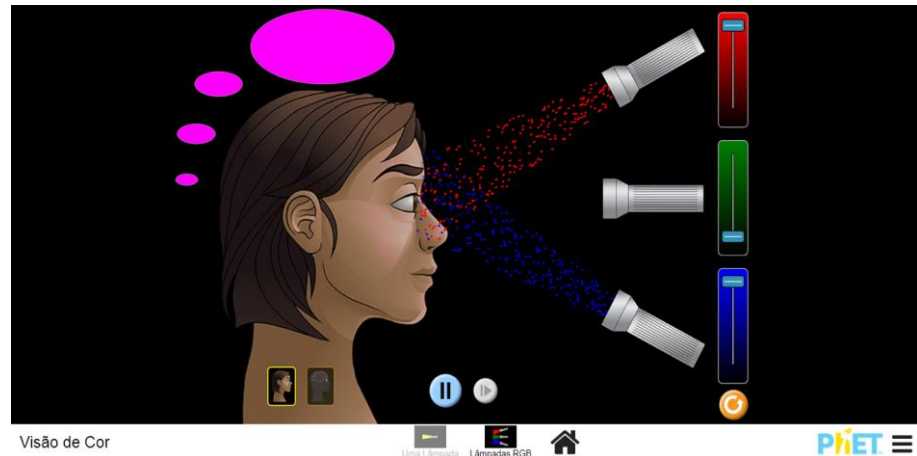


Source: PhET (2021).

4.8 Color vision

In this conception, students are allowed to understand that the colors of light can be formed by composing three primary colors (Figure 8).

Figure 8 – Visual representation of the simulation of color vision



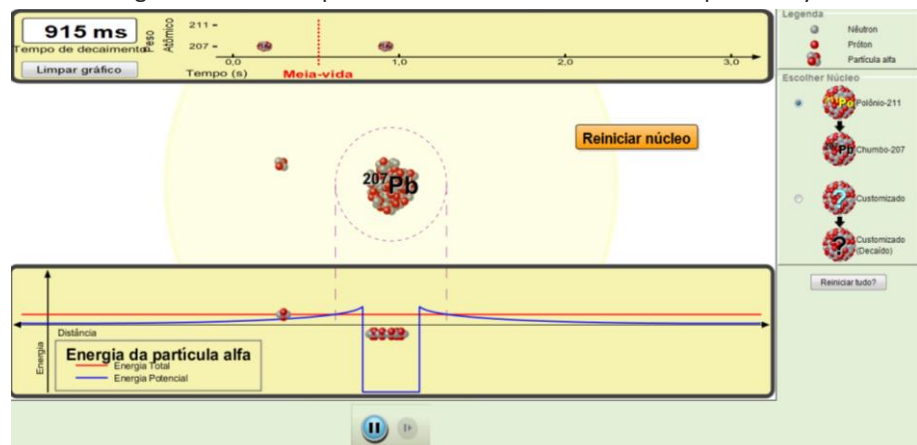
Source: PhET (2021).

The original learning objectives are to demonstrate that perceived color is the result of combinations of red, blue, and green light. Therefore, it is supported by BNCC skill EF09CI04 (PhET, 2021; BRAZIL, 2018).

4.9 Alpha decay

The present construction allows the student body to visualize the alpha particles escaping from the nucleus of a polonium atom, allowing the teacher to explore aspects related to alpha radiation and the forces that act to maintain a cohesive nucleus (Figure 9).

Figure 9 – Visual representation of the simulation of alpha decay



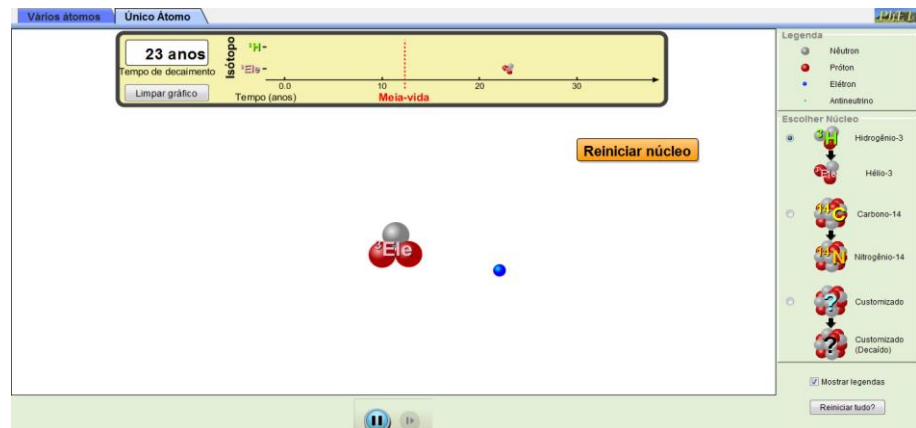
Source: PhET (2021).

The original learning goals are to demonstrate alpha radiation; explain the concept of half-life; understand the forces acting on the nucleus (strong nuclear force and Coulomb), profiling BNCC's EF09CI06 skill (PhET, 2021; BRAZIL, 2018).

4.10 Beta decay

The applied resource contemplates the visualization in the beta decay process, ensuring the teacher to understand the differences in this type of radiation.

Figure 10 – Visual representation of the simulation of beta decay



Source: PhET (2021).

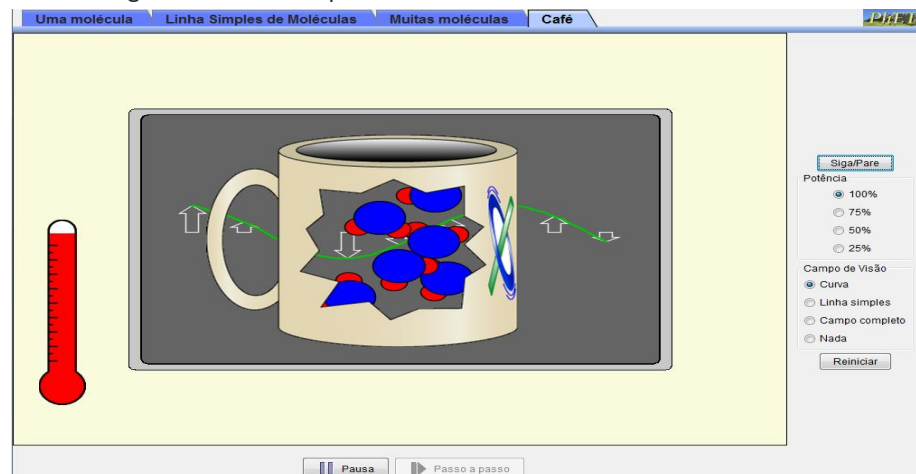
The original Learning goals are to demonstrate beta-type radiation (Figure 10), based on BNCC's EF09CI06 skill (PhET, 2021; BRAZIL, 2018).

4.11 Microwaves

This preparation consolidates the educator's work in the applications of electromagnetic radiation, while the student adjusts the frequency and amplitude of the microwaves and observes the shaking of water molecules (Figure 11).

The original learning goals are to introduce molecular movement; observe the microwave and its behavior, as is established in BNCC skill EF09CI06 (PhET, 2021; BRAZIL, 2018).

Figure 11 – Visual representation of the simulation of microwaves

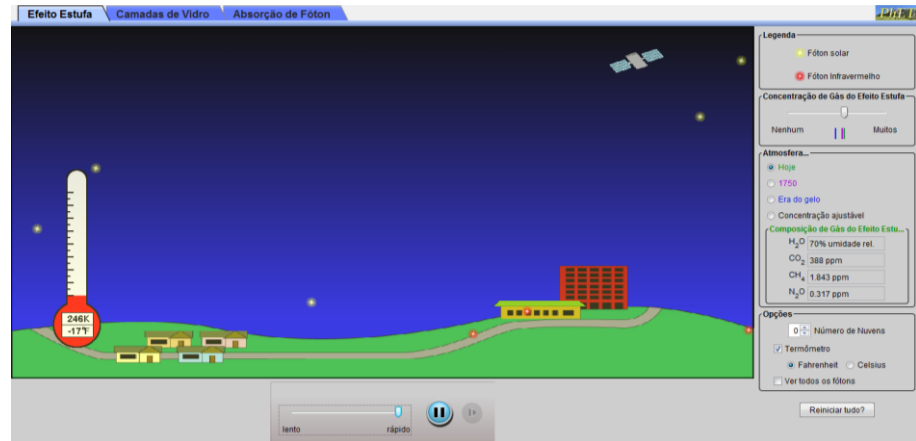


Source: PhET (2021).

4.12 Greenhouse effect

The production allows students to understand the effect of greenhouse gases on temperature (Figure 12).

Figure 12 – Visual representation of the simulation of greenhouse effect



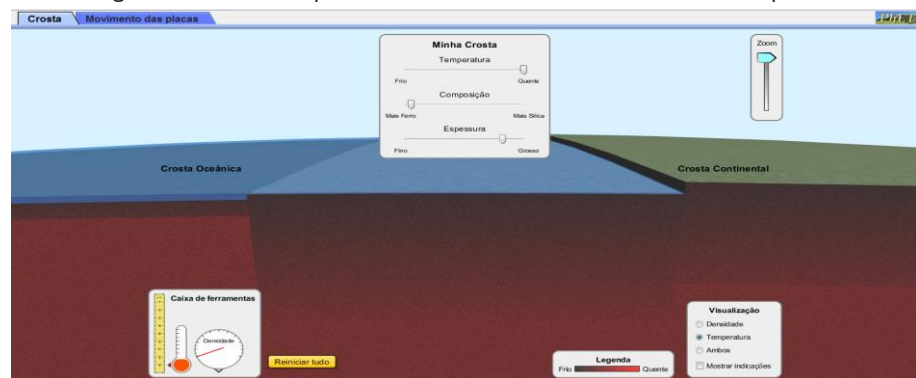
Source: PhET (2021).

The original learning goals are to demonstrate the effect of gases on temperature; describe the interaction of photons with atmospheric gases; relate the effect of clouds on photons and temperature, fixed in the BNCC skill EF07CI13 (PhET, 2021; BRASIL, 2018).

4.13 Tectonic plates

Extension allows us to understand the movement of tectonic plates in the lithosphere while altering plate temperature, composition, and thickness (Figure 13).

Figure 13 – Visual representation of the simulation of tectonic plates



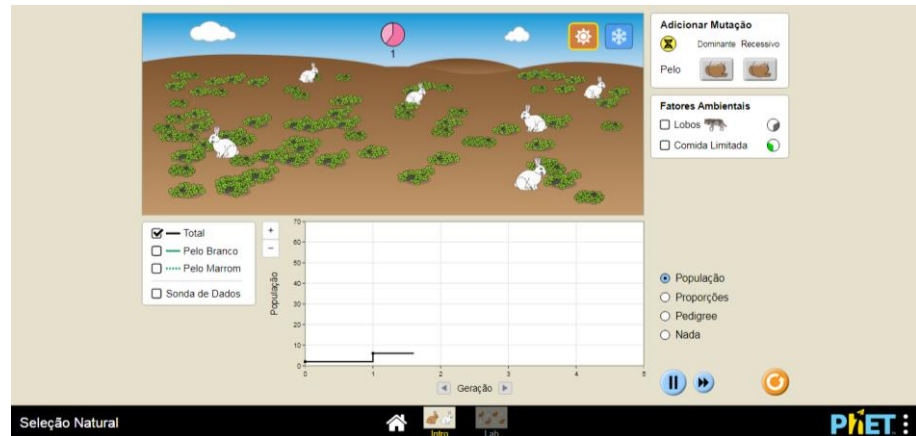
Source: PhET (2021).

The original learning goals are to demonstrate the boundaries of plates and their motions; typify the creation and destruction of the crust; infer the interference of temperature and composition in the characterization of the crust (density and buoyancy); distinguish the oceanic and continental crust, assured in the skill EF07CI15 of the BNCC (PhET, 2021; BRAZIL, 2018).

4.14 Natural selection

Retraction allows us to understand the evolution of species based on the role of natural selection (Figure 14).

Figure 14 – Visual representation of the simulation of natural selection



Source: PhET (2021).

The original learning goals are to demonstrate neutral and positive mutations; rehearse chances of survival in a given environment; tracking dominant and recessive genes in several generations of rabbits, converging with BNCC's EF09CI11 skill (PhET, 2021; BRAZIL, 2018).

5 FINAL CONSIDERATIONS

This work happened on the need to reflect on the pedagogical practices employed in the teaching of Science for the deconstruction of a content-based, mechanical, fundamentally expository teaching, which contributes to the demotivation of the student and, consequently, to school failure.

Given the above, this work analyzed interactive simulations of the PhET project at the University of Colorado, as a didactic-pedagogical resource aligned with the new Common National Curriculum Base for Natural Science teaching, in the final grades of elementary school, in order to serve as support pedagogical for the proposition of interactive activities, which place the student as a protagonist in the construction of scientific knowledge, through the use of digital tools.

This proposal suggests the use of 14 free interactive simulations, for students and teachers, as pedagogical resources by providing positive student interaction, overcoming the memorization of sometimes abstract content and concepts, included in the thematic units of Science of Nature (Matter and Energy, Life and Evolution, Earth and Universe).

The implementation of resources can be applied by teachers who believe that digital tools are important facilitators and/or enhancers in the construction and dissemination of scientific knowledge in basic education, as they motivate a generation of students who live, interact and socialize in a technological society.

SIMULAÇÕES PhET: RECURSO DIDÁTICO- PEDAGÓGICO PARA O ENSINO DE CIÊNCIAS ALINHADO À BASE NACIONAL COMUM CURRICULAR

RESUMO

O ensino de Ciências é desenvolvido frequentemente através de práticas metodológicas tradicionais que privilegiam a transposição do conteúdo previsto no currículo com um caráter apenas conceitual, fragmentado, por vezes desvinculado, que contribui para a memorização mecânica e a desmotivação do estudante. Neste cenário, o docente assume papel fundamental na busca por alternativas que privilegiem uma aprendizagem significativa, ao fomentar a formação do conhecimento de maneira ativa pelo educando, tornando as aulas mais atrativas e menos abstratas quanto aos fenômenos relativos às Ciências da Natureza. Assim, o desenvolvimento deste trabalho teve por objetivo analisar simulações interativas do projeto Physics Educacional Technology (PhET), da Universidade do Colorado, quanto às possibilidades de emprego como recurso didático-pedagógico, para o ensino de Ciências nos anos finais do ensino fundamental. Para desenvolver esse trabalho, foi realizado um levantamento da quantidade de simulações disponíveis, análises e sistematizações, quanto à unidade temática, objetos de conhecimento e habilidades à luz da Base Nacional Comum Curricular (BNCC). Os quatorze softwares selecionados e descritos nesse compêndio servirão de apoio pedagógico para a proposição de atividades interativas que promovam a construção do conhecimento científico de forma ativa, através do uso de ferramentas digitais, em detrimento da acumulação de conteúdos de forma sistemática.

PALAVRAS-CHAVE: Software de simulações. Ensino de Ciências. Base Nacional Comum Curricular.

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