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DIDACTIC TRANSPOSITION OF A MULTILEVEL VERTICAL FRAMEWORK: A CROSS-SECTIONAL PEDAGOGICAL INTERVENTION IN BASIC EDUCATION

TRANSPOSIÇÃO DIDÁTICA DE UM EIXO VERTICAL MULTINÍVEL: UMA INTERVENÇÃO PEDAGÓGICA TRANSVERSAL NA EDUCAÇÃO BÁSICA

TRANSPOSICIÓN DIDÁCTICA DE UN EJE VERTICAL MULTINIVEL: UNA INTERVENCIÓN PEDAGÓGICA TRANSVERSAL EN LA EDUCACIÓN BÁSICA

Antônio Zenon Antunes Teixeira[ab]
[a]Faculty Member of the Federal Institute of Goiás
[b]Undergraduate Student in Biology Education at Única University Center / Única College
azteixei@gmail.com

Abstract

This article examines the pedagogical and epistemological potential of the catalytic decomposition of hydrogen peroxide, popularly known as the "Elephant Toothpaste" experiment, as a multilevel vertical framework within the Natural Sciences. Grounded in the theoretical principles of didactic transposition and the proposed modeling of a spiral curriculum, this cross-sectional mixed-methods intervention evaluated a final sample of 182 basic education students. Rather than serving merely as an entertaining classroom spectacle, the practical sequence was systematically structured to align with the learners' cognitive progression. From middle school (6th to 9th grades) to high school (1st to 3rd years), the same material phenomenon was reinterpreted through increasing layers of conceptual abstraction. The intervention transitioned from macroscopic phenomenological differentiation to empirical heat transfer analysis, symbolic atomic balancing, stoichiometric mass-volume calculations, and ultimately culminated in advanced theoretical discussions on Michaelis–Menten enzyme kinetics and ideal-gas thermodynamics. The descriptive findings indicate that structured inquiry-based modeling significantly reduced traditional disciplinary fragmentation and enhanced active classroom engagement. Quantitative assessment analysis revealed robust conceptual performance, with a 92.3% success rate in macroscopic distinction in initial grades and an 84.6% success rate in ideal-gas calculations among high school seniors. The study suggests that continuous vertical modeling offers a viable, accessible strategy to strengthen foundational scientific literacy and foster intellectual autonomy.
Keywords: Didactic Transposition; Chemical Kinetics; Applied Biochemistry; Inquiry-Based Experimentation; Multilevel Teaching

Resumo

Este artigo examina o potencial pedagógico e epistemológico da decomposição catalítica do peróxido de hidrogênio popularmente conhecida como o experimento da "Pasta de Dente de Elefante" como um eixo vertical multinível nas Ciências da Natureza. Fundamentada nos princípios teóricos da transposição didática e na modelagem proposta de um currículo em espiral, esta intervenção transversal de métodos mistos avaliou uma amostra final de 182 estudantes da educação básica. Em vez de servir apenas como um espetáculo divertido em sala de aula, a

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sequência prática foi sistematicamente estruturada para se alinhar com a progressão cognitiva dos alunos. Do ensino fundamental (6º ao 9º ano) ao ensino médio (1ª à 3ª série), o mesmo fenômeno material foi reinterpretado por meio de camadas crescentes de abstração conceitual. A intervenção transitou da diferenciação fenomenológica macroscópica para a análise empírica de transferência de calor, balanceamento atômico simbólico, cálculos estequiométricos de massa-volume e, finalmente, culminou em discussões teóricas avançadas sobre cinética enzimática de Michaelis-Menten e termodinâmica de gases ideais. Os resultados descritivos indicam que a modelagem baseada em investigação estruturada reduziu significativamente a fragmentação disciplinar tradicional e aumentou o engajamento ativo em sala de aula. A análise quantitativa das avaliações revelou um desempenho conceitual robusto, com uma taxa de sucesso de 92,3% na distinção macroscópica nas séries iniciais e uma taxa de sucesso de 84,6% nos cálculos de gases ideais entre os estudantes do último ano do ensino médio. O estudo sugere que a modelagem vertical contínua oferece uma estratégia viável e acessível para fortalecer o letramento científico básico e fomentar a autonomia intelectual.
Palavras-chave: Transposição Didática; Cinética Química; Bioquímica Aplicada; Experimentação Investigativa; Ensino Multinível.

Resumen

Este artículo examina el potencial pedagógico y epistemológico de la descomposición catalítica del peróxido de hidrógeno popularmente conocido como el experimento de la "Pasta de Dientes de Elefante" como un eje vertical multinivel en las Ciencias de la Naturaleza. Fundamentada en los principios teóricos de la transposición didáctica y en el modelado propuesto de un currículo en espiral, esta intervención transversal de métodos mixtos evaluó una muestra final de 182 estudiantes de educación básica. En lugar de servir meramente como un espectáculo entretenido en el aula, la secuencia práctica se estructuró sistemáticamente para alinearse con la progresión cognitiva de los alumnos. Desde la escuela secundaria baja (6º a 9º grado) hasta la escuela secundaria alta (1º a 3º año), el mismo fenómeno material fue reinterpretado a través de capas crecientes de abstracción conceptual. La intervención transitó de la diferenciación fenomenológica macroscópica al análisis empírico de la transferencia de calor, el balanceo atómico simbólico, los cálculos estequiométricos de masa-volumen y, finalmente, culminó en discusiones teóricas avanzadas sobre la cinética enzimática de Michaelis-Menten y la termodinámica de los gases ideales. Los hallazgos descriptivos indican que el modelado estructurado basado en la indagación redujo significativamente la fragmentación disciplinaria tradicional y mejoró la participación activa en el aula. El análisis cuantitativo de las evaluaciones reveló un sólido desempeño conceptual, con una tasa de éxito del 92,3% en la distinción macroscópica en los grados iniciales y una tasa de éxito del 84,6% en los cálculos de gases ideales entre los estudiantes del último año de secundaria. El estudio sugiere que el modelado vertical continuo ofrece una estrategia viable y accesible para fortalecer la alfabetización científica fundamental y fomentar la autonomía intelectual.

Palabras clave: Transposición Didáctica; Cinética Química; Bioquímica Aplicada; Experimentación Investigativa; Enseñanza Multinivel.

1. Introduction

The fragmentation of scientific knowledge within basic education curricula hinders contemporary literacy by segmenting knowledge into isolated compartments, preventing students from understanding the totality of material phenomena and weakening their critical capacity when facing real-world problems. From the perspective of historical-dialectical materialism, overcoming this traditional model requires pedagogical praxis that restores the

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interconnectedness of knowledge through active, evidence-based investigation (Pires, Vidigal & Lima, 2026; Pereira & Teixeira, 2026; Morin, 2015).

Current curricular organizations frequently separate Chemistry, Physics, and Biology, treating them as independent bodies of concepts and formulas. This pedagogical barrier encourages students to memorize technical terminology without recognizing the inseparability of molecular processes, physical interactions, and ecological balance. From the perspective of historical-dialectical materialism, overcoming this fragmented model requires pedagogical praxis that restores the totality and historicity of knowledge through active methodologies, presenting science as a dynamic social construct in constant transformation. Consequently, scientific content gains practical meaning when students investigate the contradictions and flows of matter in real phenomena, strengthening their critical awareness of the environment.

From the perspective of historical-dialectical materialism, overcoming this mechanized model requires pedagogical praxis that restores the totality and historicity of knowledge through active methodologies (Sánchez Vázquez, 1977). Science must be presented as a dynamic social construct in constant transformation. Investigating the contradictions and flows of matter enables students to develop critical awareness of their environment (Chassot, 2018).

Active methodologies and inquiry-based laboratory practices emerge as essential mechanisms of rupture against the cognitive passivity of purely expository teaching. Within this framework, didactic transposition defines the rigorous process of transforming scholarly knowledge into accessible taught knowledge without sacrificing conceptual accuracy (Chevallard, 1991). Complementarily, a spiral curriculum suggests that complex conceptual cores can be revisited repeatedly across different schooling stages, provided that each iteration respects the learners' biological and developmental maturity (Bruner, 1969).

In this context, inquiry-based experimentation should not be understood merely as an illustrative resource that supports textbook content, but as a catalyst for epistemological rupture (Bachelard, 1996). Direct engagement with

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physicochemical phenomena generates the cognitive conflict necessary to destabilize common-sense explanations. Laboratory activity thus becomes a space in which students test hypotheses against material evidence (Carvalho, 2004).

Didactic transposition, a fundamental concept in teacher education, defines the process of transforming an object of scholarly knowledge into an object of taught knowledge while preserving conceptual rigor. In science education, this process requires methodological refinement by the educator so that complex theories can be adapted to students' developmental levels without reducing scientific accuracy. When combined with a spiral curriculum, didactic transposition allows the same conceptual core to be revisited across schooling stages, with each iteration adding greater abstraction, mathematical formalization, and conceptual depth to prior knowledge.

The concept of the spiral curriculum supports the premise that any subject can be taught correctly and honestly to any child, provided that the learner's developmental stage is respected. Periodically returning to the same physicochemical phenomenon increases the density of learning over time. Each new approach adds layers of abstraction, mathematical formalization, and conceptual depth to prior knowledge (Bruner, 1969).

The catalytic decomposition of hydrogen peroxide (H_2O_2), commonly known as the "Elephant Toothpaste" experiment, has considerable visual appeal because it produces a rapid expansion of oxygen-rich foam. The sudden volumetric growth of the system immediately captures students' attention and curiosity. This playful dimension makes the activity a strategic pedagogical resource for introducing Natural Sciences (Souza et al., 2018).

However, the literature points out that the purely performative use of experiments as a "visual show" drains the cognitive potential of practical activity. When the foam serves merely to entertain, the classroom drifts away from the scientific method and toward spectacle. The true value of the activity lies in the teacher's ability to transform visual impact into guiding questions and lines of investigation (Galiazzi & Gonçalves, 2004; Hodson, 1994).

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From a chemical perspective, the reaction consists of the decomposition of hydrogen peroxide into liquid water and gaseous oxygen, accompanied by the release of thermal energy. It provides an accessible yet conceptually rich system for studying chemical kinetics, stoichiometric principles, and introductory and advanced thermodynamics. The simplicity of the reagents contrasts with the variety of physical variables that influence reaction rate and product formation (Rocha et al., 2024).

From a biological perspective, the use of catalase extracted from yeast (*Saccharomyces cerevisiae*) introduces the study of biological catalysis into the system (Teixeira & Souza, 2025). Catalase is a highly efficient enzyme found in cellular peroxisomes and is responsible for protecting cellular integrity against oxidative stress (Nelson & Cox, 2019). The reaction, therefore, becomes a natural bridge between inorganic chemistry and cytology (Junqueira & Carneiro, 2012).

At the transition to the early years of middle school, particularly in the 6th grade, the experiment assumes a predominantly phenomenological character. The methodological focus is on developing students' observational skills so that they can identify clues that distinguish physical phenomena from chemical transformations (Brasil, 2018). In this context, the foam serves as visible macroscopic evidence that matter has undergone an irreversible reorganization (Silva, 2020; Fogaça, 2024).

As students progress through school, the 7th and 8th grades require the incorporation of thermal processes and introductory atomic models into the interpretation of the phenomenon. The heat perceived on the wall of the flask supports the concept of an exothermic reaction in thermology, while writing the equation on the board introduces the need for stoichiometric balancing and an initial understanding of energy activation. In this way, invisible matter gradually acquires symbolic representation (Silva et al., 2023).

By the end of middle school, in the 9th grade, the activity consolidates students' understanding of stoichiometric laws, with particular emphasis on Lavoisier's Law of Conservation of Mass. Students are challenged to track the original atoms and recognize that mass is conserved despite the formation of

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gaseous and liquid products. This dynamic supports the transition to the more formal study of the exact sciences in high school (Lopes, 2021).

In high school, the phenomenon is reframed from a qualitative demonstration into a rigorous quantitative and thermodynamic object of study. In the 1st year, students apply the ideal-gas laws and stoichiometric relationships to calculate the mass of water produced, and the volume of oxygen released at STP based on the concentration (volume strength) of the hydrogen peroxide used (Fogaça, 2026; Atkins & De Paula, 2018; Giordan, 1999).

In the 2nd year of high school, returning to the same foam-based activity first introduced in the 6th grade encourages students to confront earlier playful understandings with their present scientific maturity. At this stage, they reinterpret the phenomenon through collision theory, recognizing that reaction acceleration depends on effective molecular orientation and is enhanced by the catalyst's active site (Kotz, Treichel, & Townsend, 2016).

The highest level of theoretical density and methodological sophistication occurs in the 3rd year of high school, where the experiment becomes a platform for biochemistry and applied kinetics. At this point, visual appeal gives way to deeper analytical discussion of Michaelis–Menten saturation kinetics, allosteric inhibition, and the effects of environmental conditions on protein structure (Nelson & Cox, 2019).

This integrated approach helps bridge the pedagogical gap that often separates textbook theory from laboratory practice. By revisiting the same phenomenon through different conceptual lenses, the study reduces curricular fragmentation and supports the development of durable procedural memory. Repeating the experiment reinforces the idea that scientific knowledge is built through interconnected explanatory models (Almeida & Mannarino, 2015).

Moreover, the scientific literacy fostered through this pedagogical strategy equips students to face higher-education entrance examinations, including the ENEM (Brasil, 2018). The ability to interpret activation-energy graphs and relate

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enzymatic denaturation to the disruption of tertiary structure strengthens students' intellectual autonomy. In this process, biochemistry ceases to be merely decorative content and assumes a functional explanatory role (Nelson & Cox, 2019).

Considering the above, investigating the potential of spiral experimentation as an organizing axis for Natural Sciences teaching becomes especially relevant. Accordingly, this study pursued the following general objectives:

- To analyze the effectiveness of the multilevel didactic transposition applied to the "Elephant Toothpaste" experiment from the 6th grade of middle school to the 3rd year of high school;
- To map students' cognitive gains and the development of scientific literacy as they reinterpret the same physicochemical phenomenon at different levels of mathematical, thermodynamic, and biochemical abstraction;
- To validate continuous inquiry-based experimentation as a means of overcoming curricular fragmentation and consolidating students' intellectual autonomy.

The catalytic decomposition of hydrogen peroxide (H_2O_2) offers a strategically dense and visually engaging system to operationalize this vertical progression. While its rapid volumetric expansion immediately captures attention, its authentic value lies in its capacity to serve as a continuous bridge connecting inorganic chemistry, stoichiometry, thermodynamics, cytology, and applied biochemistry. This study aims to analyze the descriptive viability of a multilevel vertical transposition of this single material phenomenon, mapping the students' cross-sectional performance and outlining a replicable model for interdisciplinary integration.

2. Literature Review

The integration of Chemistry and Biology through inquiry-based experimentation has gained prominence in science education research because authentic phenomena defy disciplinary boundaries. Contemporary frameworks show that scientific literacy develops more effectively when students construct conceptual

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relationships across domains rather than studying isolated content, positioning interdisciplinary practical activities as central strategies for promoting conceptual understanding, problem-solving skills, and long-term knowledge retention (Chassot, 2018; Morin, 2015).

Inquiry-based laboratory activities consistently enhance students' motivation and conceptual development by encouraging them to formulate hypotheses, collect evidence, and construct explanations. Experimentation fulfills its educational purpose only when students actively participate in the investigative process through questioning and scientific inquiry, rather than merely observing spectacular phenomena, thereby enabling the development of epistemological autonomy (Carvalho, 2004; Hodson, 1994; Galiazzi & Gonçalves, 2004).

Didactic transposition adapts scientific knowledge to different educational stages, ensuring that scholarly knowledge undergoes systematic transformation to make concepts accessible while preserving scientific rigor (Chevallard, 1991, 1998). This process is crucial in science education to decode abstract microscopic processes, requiring careful sequencing of concepts, representations, and practical activities according to the learners' cognitive development.

Bruner's spiral curriculum complements didactic transposition by suggesting that complex scientific concepts can be revisited repeatedly throughout schooling at progressively higher levels of abstraction. Rather than introducing entirely new topics annually, this iterative structure promotes cumulative conceptual refinement, strengthens retention, facilitates learning transfer, and reduces curricular fragmentation by connecting new knowledge with previously established mental models (Bruner, 1969).

Within Chemistry education, practical experiments involving hydrogen peroxide decomposition have become popular because they combine visual appeal with substantial conceptual richness. The "Elephant Toothpaste" experiment has been widely employed to introduce concepts such as chemical reactions, catalysts, exothermic processes, gas formation, reaction kinetics, and stoichiometry (Souza et al., 2018; Rocha et al., 2024; Silva et al., 2023). However, several authors warn that the experiment is frequently reduced to an entertaining classroom demonstration,

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limiting its educational value. When teachers emphasize only the rapid foam production, opportunities for deeper scientific reasoning may be lost (Hodson, 1994; Galiazzi & Gonçalves, 2004).

From a biological perspective, using yeast for hydrogen peroxide decomposition introduces enzyme catalysis and cellular metabolism, utilizing catalase to model enzyme specificity, oxidative stress, peroxisomal function, and protein structure (Nelson & Cox, 2019; Junqueira & Carneiro, 2012). While this reaction simultaneously bridges chemical kinetics and biological catalysis, most published educational activities focus on either discipline independently, rarely exploring the phenomenon as a continuous, multilevel interdisciplinary teaching sequence.

Research on active methodologies supports contextualized experimentation, as active learning environments enhance engagement by positioning students as protagonists in knowledge construction rather than passive recipients [Moran, 2021]. Similarly, project-based and inquiry pedagogies encourage collaborative problem-solving, scientific communication, and critical reflection, demonstrating high effectiveness when systematically integrated into curricular planning rather than treated as isolated events (Oliveira, Souza & Teixeira, 2023).

Despite advances in inquiry-based science education, most studies investigate isolated experimental interventions within single educational levels or disciplinary contexts. Little attention has been devoted to pedagogical models that revisit the same scientific phenomenon across schooling years through progressively sophisticated conceptual interpretations. Consequently, empirical evidence remains limited regarding how a single experiment functions as an organizing axis for didactic transposition, interdisciplinary integration, and cumulative scientific literacy.

The present study addresses this gap by examining the “Elephant Toothpaste” experiment as a multilevel pedagogical framework spanning middle school and high school. Grounded in didactic transposition, inquiry-based experimentation, and the spiral curriculum, the research investigates how repeated reinterpretation of a single physicochemical phenomenon can support increasingly

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complex understandings of chemistry, biology, and thermodynamics while reducing curricular fragmentation and strengthening students' scientific literacy.

3. Methodology

This cross-sectional pedagogical intervention analyzed the continuous modeling and didactic transposition of a single physicochemical phenomenon in basic education. Grounded in historical-dialectical materialism, the study examined how scholarly knowledge is transformed into taught knowledge through structured inquiry-based experimentation (Chevallard, 1991). The intervention was conducted at a private school in Aparecida de Goiânia during the first academic semester of 2026 and involved middle school and high school classes.

3.1 Participants and Sample Delimitation

The sample comprised 182 students regularly enrolled in the morning shift at the partner institution. Participants were distributed across educational levels to enable spiral monitoring of scientific literacy (Bruner, 1969):

Middle School (Grades 6 to 9; N = 104): Grade 6 (n = 26); Grade 7 (n = 28); Grade 8 (n = 24); Grade 9 (n = 26).

High School (Years 1 to 3; N = 78): Year 1 (n=28); Year 2 (n=24); Year 3 (n=26).

3.2 Ethical and Legal Safeguards

This work is an experience report of a descriptive nature, grounded in qualitative reflection on pedagogical praxis. The records analyzed here were generated during the Supervised Curricular Internship for the Degree in Biological Sciences, conducted in the first semester of 2026, and were used exclusively to reflect on teaching, learning, and professional training.

A field diary recorded unsystematic observations regarding classroom dynamics, methodologies, and environmental interactions. Because these records were not originally planned as a research project involving human participants, the

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report is exempt from registration and evaluation by the CEP/Conep System under Art. 1, Sole Paragraph, Item VII of Resolution CNS No. 510/2016. To ensure ethical integrity, all institutions and participants were anonymized through generic nomenclature.

3.3 Experimental Protocol and Biosafety Measures

The procedure evaluated the catalytic decomposition of hydrogen peroxide into liquid water and oxygen gas. In accordance with biosafety guidelines (CDC), the corrosive 40-volume H_2O_2 solution (12% w/w) was handled exclusively by the teacher using an acrylic splash shield, a fume hood, nitrile gloves, and safety goggles. Students manipulated only low-risk solutions (3% and 6%) wearing standard lab coats, gloves, and protective eyewear. The emergency eyewash station was verified before each session, and residual waste was neutralized and discarded according to local environmental regulations, resulting in zero chemical incidents.

Table 1: Standardized Experimental Protocol by Educational Grade

Grade/Year Level	Reagents and Concentrations per Assay (n = 3)	Manipulation Type	Primary Conceptual Framework
6th and 7th Grades	50 mL H_2O_2 (3% / 10 Vol), 10 mL detergent, 5g active dry yeast in 30 mL water (37 °C)	Teacher Demonstration / Student Observation	Phenomenological clues, macroscopic changes, and heat transfer.
8th and 9th Grades	50 mL H_2O_2 (6% / 20 Vol), 10 mL detergent, 5g active dry yeast in 30 mL water (37 °C)	Guided Student Collaboration	Symbolic representation, balancing, and mass conservation laws.
1st and 2nd Years HS	50 mL H_2O_2 (6% / 20 Vol), 10 mL detergent, 5g active dry yeast in 30 mL water (37 °C)	Active Student Execution	Classical mass-mass stoichiometry and collision geometry.
3rd Year HS	50 mL H_2O_2 (12% / 40 Vol), 10 mL detergent, 5g active dry yeast in 30 mL water (37 °C)	Exclusive Teacher Handling	Advanced biochemistry, thermodynamics, and ideal-gas laws.

3.4 Data Collection and Analytical Integration

A multidimensional data structure was integrated to secure analytical consistency:

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1. **Qualitative Field Diary**: Systematized descriptive notes compiled by the teacher-researcher immediately after each session, mapping contextual behaviors.

2. **Investigation Worksheets**: Individual, task-based laboratory exercises evaluating technical terminology and chemical calculations.

3. **Summative Written Assessments**: Institutional, closed-book bimonthly exams embedded with target open-ended items to assess abstract conceptual representation. All quantitative percentages correspond to the absolute number of correct responses over total participants present (n/N), evaluated under validated correction rubrics (provided in Supplementary Material).

3.5 Reagents and Experimental Apparatus

The central activity was based on the catalytic decomposition of hydrogen peroxide (H_2O_2), with quantitative and volumetric adaptations tailored to each level of conceptual complexity in classroom and laboratory settings. Standardized materials were used for demonstrations and guided student participation:

- Graduated glass cylinders (250 mL and 500 mL) and borosilicate beakers;
- Transparent plastic containment basins for collecting the expansion volume;
- Commercial stabilized liquid hydrogen peroxide at concentrations of 10 volumes (3%), 20 volumes (6%), and 40 volumes (12%);
- Commercial neutral liquid detergent (gas trapping agent);
- Varied food colorings (visual flow indicators);
- Organic catalysts: dry active yeast (*Saccharomyces cerevisiae*) activated in warm water (≈ 37 °C);
- Digital chemical thermometers (scale from -50 °C to 300 °C) and precision stopwatches.

3.6 Didactic-Pedagogical Procedures by Education Level

The methodological design followed a trajectory of conceptual and mathematical rescaling of the phenomenon, strategically organized into four axes of guided pedagogical intervention:

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3.6.1 Phenomenological and Thermal Axis (6th and 7th Grades)

In the 6th grade, the experiment was performed on the central bench by the lead teacher, while students acted as active observers using field guides to record visual clues. The emphasis was on identifying chemical transformation through the release of invisible gases trapped by the detergent. In the 7th grade, the intervention incorporated introductory thermodynamics. Using protective gloves, students measured temperature before and after peak expansion, recording the thermal variation (ΔT) to support discussion of enthalpy and exothermic reactions in calorimetry (Lopes, 2021).

3.6.2 Atomic Structure and Stoichiometric Laws Axis (8th and 9th Grades)

In the 8th grade, the methodology shifted toward symbolic representation and atomic modeling. Students were challenged to balance the chemical equation for hydrogen peroxide decomposition on the board, and the concept of activation energy (E_a) was introduced. In the 9th grade, the reaction was used to reinforce stoichiometric laws, especially Lavoisier's Law of Conservation of Mass, as well as basic collision theory. Students completed a guided notebook activity in which they calculated the number of particles generated by molecular rearrangement (Lopes, 2021).

3.6.3 Stoichiometric and Volumetric Axis (1st and 2nd Years of High School)

In the 1st year, the playful demonstration was replaced by a rigorous quantitative investigation. Students used the concentration of the hydrogen peroxide solution to apply classical stoichiometric relationships and determine the theoretical mass of water produced. In the 2nd year, the cycle repeated the same experimental design previously used in the 6th grade. The aim was to generate cognitive conflict by requiring students to reinterpret the same foam-based phenomenon through the lens of reaction rates and the geometric alignment of effective collisions per second (Kotz, Treichel, & Townsend, 2016).

3.6.4 Biochemistry and Advanced Kinetics Axis (3rd Year of High School)

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In the 3rd year, the activity became a practical lesson in advanced biochemistry and applied molecular kinetics. The methodological pathway centered on three post-experiment topics for analytical discussion (Nelson & Cox, 2019):

- **Enzyme Biochemistry**: Investigation of the active site of the yeast catalase enzyme and cellular protection within peroxisomes against oxidative stress.

- **Advanced Chemical Kinetics**: Board demonstration of the lowering of the activation energy barrier by the enzyme, saturation factors, and maximum velocity (V_{max}), alongside a theoretical simulation of tertiary structure collapse (protein denaturation) induced by thermal stress or extreme pH.

- **Senior Thermodynamics**: Calculation of the standard enthalpy change ($\Delta H° = -196$ kJ) and application of the Clapeyron equation to predict the volume of gas released at standard temperature and pressure (STP).

3.7 Data Collection Instruments and Evaluative Analysis

Data collection was structured in a multidimensional way to ensure continuous monitoring of scientific literacy and student autonomy (Sasseron & De Carvalho, 2011). Three main instruments were used:

- **Lead Teacher's Field Diary**: A descriptive record of classroom engagement, emerging questions, and students' responses during the experiment;
- **Written Investigation Worksheets**: Individual classroom exercises and reports evaluated for the accurate use of technical terminology and the correctness of mathematical reasoning;
- **Bimonthly Summative Assessments**: Integrated written questions administered at the end of the first academic period to assess students' interpretation of thermodynamic and kinetic representations.

4. Results and Discussion

The results of the pedagogical intervention indicate that the "Elephant Toothpaste" experiment operated both as a catalyst for student engagement and as

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an effective axis of didactic transposition. The combined analysis of field diaries, written reports, and summative assessments showed that the methodological flexibility of the activity corresponded closely to students' cognitive development (Rocha, 2024). Curricular fragmentation was reduced by integrating concepts from Physics, Chemistry, and Biology around a single material phenomenon, in accordance with the guidelines of the National Common Curricular Base (Brasil, 2018; Giordan, 1999).

4.1 Phenomenological and Thermal Gradation (6th and 7th Grades)

In the 6th grade (N=26), the initial baseline record indicated that 78% of the students mixed the macroscopic production of foam with the physical process of water boiling. Guided mediation redirected their attention toward permanent indicators, leading 24/26 (92.3%) of the class to accurately categorize the irreversible transformation on their individual worksheets (Giordan, 1999; Lopes, 2021).

In the 7th grade (N=28), digital thermometers placed directly inside the reacting media recorded a mean temperature variation of $\Delta T = +24^{o}C$ ($\pm$ 1.2^{o}C). This immediate physical measurement allowed 24/28 (85.7%) of the students to correctly characterize the phenomenon as a strongly exothermic reaction, translating abstract calorimetry definitions into concrete sensory experiences (Mortimer & Amaral, 1998).

4.2 Atomic Modeling and Mass Conservation (8th and 9th Grades)

In the 8th grade (N = 24), atomic coordinate charts on the board enabled 21/24 (87.5%) of the students to complete the stoichiometric coefficients through structured trial and error, introducing the concept of activation energy as an energetic barrier. Completion of the board-based coordination chart showed that 87.5% of students were able to infer, through trial and error, the need for stoichiometric balancing and to relate coefficients to atomic organization (Lima, Goes, & Fernandez, 2025). Students assimilated the concept of activation energy (E_a) when they recognized that, although hydrogen peroxide is unstable, its decomposition still requires a reduction in the energy barrier before large-scale

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energy release can occur, thereby moving beyond purely technical memorization (Kotz, Treichel, & Townsend, 2016).

In the 9th grade (N=26), 23/26 (88.4%) of the students correctly explained that total mass is rigorously conserved despite the release of trapped gases. The teacher highlighted that while weight decreases on an open digital scale because oxygen escapes, the absolute number of atoms remains identical, preventing common-sense misinterpretations of Lavoisier's Law. Students were able to trace the atoms present in the reactants and explain, in both verbal and mathematical terms, why total mass remained constant despite the formation of gaseous and liquid products. Their notebook calculations also suggested that collision-based reasoning provided a solid foundation for understanding chemical kinetics (Chang & Overby, 2013).

4.3 Quantitative Mass and Volumetric Calculations (1st and 2nd Years HS)

In the 1st year of High School (N = 28), the pedagogical intervention systematically moved beyond mere macroscopic curiosity to demand rigorous mathematical validation of the material phenomenon. During the written summative evaluation, 24/28 (85.7%) of the students successfully calculated the exact mass of liquid water produced from the chemical decomposition of 50 mL of a commercial 6% (w/w) H_2O_2 solution. This performance indicates a high level of operational mastery regarding the law of definite proportions and mass-mass stoichiometry, demonstrating that the conceptual abstraction of the chemical equation can be effectively consolidated when anchored in an inquiry-based empirical background (Kotz, Treichel & Townsend, 2016). The classroom discourse mapping recorded in the field diary revealed that anchoring numerical calculation within a previously observed spatial expansion drastically mitigated the traditional learning blockages associated with scientific symbolism, converting abstract algorithmic manipulation into a meaningful tool for material quantification, in strict alignment with the principles of authentic didactic transposition (Maldaner, 2000).

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In the 2nd year (N=24), revisiting the exact experimental arrangement first observed during their middle school years generated an environment of sustained concentration. Moving beyond playful excitement, 21/24 (87.5%) of the students explained the catalytic acceleration through collision theory, defining the active site's geometric role in lowering the transition state barrier. (Bruner, 1969; Kotz, Treichel, & Townsend, 2016).

4.4 Advanced Biochemistry and Thermodynamics (3rd Year HS)

The highest layer of conceptual density was achieved in the 3rd year (N=26), where 24/26 (92.3%) of the students identified the active dry yeast catalyst as a source of endogenous intracellular catalase found within cellular peroxisomes to defend cell integrity against oxidative stress rather than treating it as a purified enzyme extract. Regarding graphical data interpretation, 23/26 (88.4%) of the students successfully interpreted Michaelis–Menten kinetic curves, identifying the maximum velocity (V_{max}) saturation phase and correlating thermal protein denaturation with structural disruption of the active site without peptide bond cleavage (Nelson & Cox, 2019).

Furthermore, 21/26 (80.8%) of the senior students successfully demonstrated a conceptual understanding of the Michaelis constant (K_m), correctly defining it on the evaluation sheets as the specific substrate concentration at which the reaction velocity reaches half of its maximum value ($V_{max}/2$). Data from the field diary indicated that during the collaborative board-based mapping, students grasped that a lower (K_m) value reflects a higher affinity between the endogenous catalase enzyme and the hydrogen peroxide substrate (Nelson & Cox, 2019). This toxicological link allowed the class to rationalize why cells maintain highly efficient peroxisomal systems capable of rapid saturation even under trace concentrations of oxidative stress subproducts, transforming abstract mathematical variables into clear indicators of cellular survival and metabolic adaptation.

In senior thermodynamics, students used bond enthalpies to derive the reaction's standard enthalpy variation ($2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$; $\Delta H° = -196$

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kJ). Finally, 22/26 (84.6%) of the students successfully applied the ideal gas law (PV = nRT) to predict the absolute volume of gaseous O_2 released at standard conditions (0 °C, 1 atm), demonstrating advanced interdisciplinary integration across physical and molecular boundaries (Nelson & Cox, 2019).

Students also demonstrated an advanced ability to interpret kinetic graphs. Activation-energy diagrams drawn on the board with contrasting colors facilitated their understanding of how enzymes lower the energy barrier to the transition state, while Michaelis–Menten curves helped them distinguish the proportional acceleration phase from the saturation phase defined by maximum velocity (V_{max}), when catalytic capacity is fully occupied. Their reports also showed that they understood how extreme temperatures or drastic pH changes can deform the active site and inactivate the enzyme without breaking the peptide bonds of the primary structure (Nelson & Cox, 2019).

Understanding of molecular disruption through protein denaturation was also strong. Students accurately predicted that exposing live yeast to extreme temperatures or drastic pH changes would disrupt the interactions responsible for tertiary and quaternary structure. Their reports showed that they understood how deformation of the active site can permanently inactivate the enzyme without breaking the peptide bonds of the primary structure (Nelson & Cox, 2019).

The senior thermodynamics and ideal-gas stoichiometry calculations applied in the 3rd year brought the bimonthly period to a close with a high level of mathematical rigor. Students successfully applied formation and bond-enthalpy concepts to calculate the standard enthalpy change of hydrogen peroxide decomposition, obtaining a thermochemical value of $\Delta H° = -196$ kJ. The application of the ideal gas equation to predict the volume of oxygen gas (O_2) released at STP yielded an 84% success rate on the exercise lists, demonstrating the close connection between molecular biology and the physical laws governing gases (Atkins & De Paula, 2018).

Comparative analysis of the lead teacher's field diary indicated that the systematic use of project-based learning reduced recurrent classroom-management problems across the evaluated grades (Oliveira, Souza, & Teixeira, 2023; Teixeira &

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Souza, 2025). Replacing passive copying with evidence-based investigative experimentation kept students continuously engaged. The enthusiasm generated by the foam phenomenon was therefore redirected toward the cognitive effort required to solve mathematical and biochemical problems in their notebooks.

The results also revealed operational challenges during the teaching sequence. The 50-minute class period proved insufficient to fully explore allosteric kinetics in the 3rd year and more complex volumetric calculations in the 1st year. This time constraint required careful pacing by the lead teacher and the strategic use of a partially pre-structured board so that enough time remained for guided correction of the reinforcement tasks (Maldaner, 2000).

Another challenge identified in the field diaries was the persistence of common-sense evolutionary language among some 9th-grade students. Even after the practical activity, a few students continued to use Lamarckian formulations, claiming that organisms mutate because they need to adapt to the environment. Immediate board-based clarification was therefore needed to distinguish random genetic variation from environmental selection, thereby strengthening evolutionary literacy (Bizzo, 2009).

Ongoing monitoring as the teacher moved between desks proved to be an indispensable diagnostic tool. This individualized support made it possible to identify that, although most students had mastered the mechanics of the equations, a smaller group still struggled with operations involving sign inversion and thermal balances. The formation of productive peer groups, in which more advanced students helped support their classmates, resolved these difficulties and strengthened classroom cooperation (Torres, 2004).

The review and tutoring sessions carried out through the collection and checking of activity portfolios at the end of the bimonthly period attested to the classes' commitment to homework. The completion rate for the textbook activities reached 94%. This detailed review suggested that continuous experimentation increased students' interest in reading complementary science and biology texts at home.

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The corrective feedback provided after the return of the written assessments functioned as an effective mechanism for pedagogical leveling. Discussing the questions with the highest error rates step by step on the board reduced conceptual gaps and helped ensure that the BNCC skills planned for the period were consolidated (Brasil, 2018). Students demonstrated cognitive resilience by revising their own mistakes in enthalpy calculations and periodic-table coordinates.

4.5 Reflexivity, Peer Collaboration, and Institutional Limitations

Qualitative analysis of the teacher's field diary confirmed that replacing passive copying with project-based, evidence-driven tasks significantly minimized classroom management disruptions. The visual appeal of the foam was successfully channeled into cognitive effort. Individual monitoring between desks revealed that while the majority mastered the chemical formulas, a smaller subset struggled with sign inversion in thermal balances; this was resolved by establishing productive peer-tutoring groups.

The main operational limitation identified was the strict 50-minute class duration, which proved insufficient to fully explore allosteric interactions or complex volumetric calculation series. This constraint required a pre-structured whiteboard layout to secure adequate time for collective correction. Furthermore, the lack of a longitudinal cohort design means these findings must be interpreted as a viable curricular blueprint for vertical transposition rather than verified long-term cognitive retention metrics.

Overall, the findings indicate that the vertical spiral trajectory organized around the “Elephant Toothpaste” experiment successfully met the study’s proposed objectives. The evidence supports the premise that Natural Sciences teaching becomes more effective when theory and laboratory practice are integrated through a dynamic and contextualized pathway (Oliveira, Souza, & Teixeira, 2023; Teixeira & Souza, 2025). In this sense, the experience reinforces didactic transposition as a powerful tool for scientific literacy and educational humanization.

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The relevance of these results extends beyond the school's internal context, offering a replicable model of integrated curricular design for middle and high school. Demonstrating that the same chemical experiment can support learning from phenomenological differentiation to advanced thermodynamics opens pathways for overcoming school fragmentation. The intellectual autonomy developed by the students reinforces the role of active experimentation as a central driver of academic excellence and citizenship education.

5. Conclusion

The cross-sectional evaluation of this multilevel pedagogical intervention validates the descriptive viability of using a single material phenomenon as an organizing framework for the vertical transposition of science curricula. Reinterpreting the catalytic decomposition of hydrogen peroxide through progressive layers of mathematical and biochemical abstraction successfully aligned with the distinct developmental stages of basic education students. By replacing passive routines with active, clue-driven inquiry, students advanced from basic phenomenological observation to advanced thermodynamic and enzymatic modeling, fulfilling the integrative principles required by contemporary educational guidelines. While institutional time limits represent an operational barrier, the high descriptive performance rates and the reduction in classroom indiscipline suggest that continuous vertical modeling offers a robust, scalable strategy to foster intellectual autonomy and enrich scientific literacy in school environments.

References

ALMEIDA, Carolina de Arsolino; MANNARINO, Ludmila Amitrano. *A importância da aula prática de ciências para o Ensino Fundamental II*. Revista Ibero-Americana de Humanidades, Ciências e Educação, *[S. l.]*, v. 7, n. 8, p. 787-799, 2021. DOI: 10.51891/rease.v7i8.2015. Disponível em: https://periodicorease.pro.br/rease/article/view/2015. Acesso em: 26 maio 2026.

ATKINS, Peter; DE PAULA, Julio. *Físico-química: volume 1: termodinâmica e cinética*. 10. ed. Rio de Janeiro: LTC, 2018.

REMUNOM
ISSN 2178-6925

Received: 29/06/2026 - **Accepted:** 30/07/2026
Vol: 13.17
DOI: 10.66104/2691fa20
Pages: 1-25

BACHELARD, Gaston. *A formação do espírito científico: contribuição para uma psicanálise do conhecimento*. Tradução de Estela dos Santos Abreu. Rio de Janeiro: Contraponto, 1996.

BIZZO, Nélio. *Ciências: fácil ou difícil?* 4. ed. São Paulo: Biruta, 2009.

BRASIL. Ministério da Educação. *Base Nacional Comum Curricular (BNCC): Ensino Médio*. Brasília: MEC, 2018.

BRASIL. Ministério da Educação. Secretaria de Educação Média e Tecnológica. *Parâmetros Curriculares Nacionais (PCN): Ensino Médio*. Brasília: MEC/SEMTEC, 1999/2002.

BRUNER, Jerome S. *O processo da educação*. Tradução de Lygia Arcângela da Rocha Dorea. São Paulo: Nacional, 1969.

CARVALHO, Anna Maria Pessoa de. *O papel da experimentação no ensino de Ciências*. In: CARVALHO, Anna Maria Pessoa de (org.). *Ensino de Ciências: múltiplas facetas*. São Paulo: Cortez, 2004.

CHANG, Raymond; OVERBY, Jason. *Química Geral*. 11. ed. Porto Alegre: AMGH, 2013.

CHASSOT, Attico. *Alfabetização científica: questões e desafios para a educação*. 7. ed. São Paulo: Cortez, 2018.

CHEVALLARD, Yves. *La transposición didáctica: del saber sabio al saber enseñado*. 3. ed. Buenos Aires: Aique, 1998.

CHEVALLARD, Yves. *La transposition didactique: du savoir savant au savoir enseigné*. 2. ed. Grenoble: La Pensée Sauvage, 1991.

FAZENDA, Ivani Catarina Arns. *Interdisciplinaridade: história, teoria e pesquisa*. 18. ed. Campinas: Papirus, 2011.

FOGAÇA, Jennifer Rocha Vargas. *Pasta de dente de elefante*. Educador Brasil Escola, 2024. Disponível em: https://educador.brasilescola.uol.com.br/estrategias-ensino/pasta-dente-elefante.htm. Acesso em: 25 maio 2026.

FOGAÇA, Jennifer Rocha Vargas. *Reações de oxirredução envolvendo água oxigenada*. Brasil Escola, 2026. Disponível em: https://brasilescola.uol.com.br/quimica/reacoes-oxirreducao-envolvendo-agua-oxigenada.htm. Acesso em: 26 maio 2026.

REMUNOM
ISSN 2178-6925

Received: 29/06/2026 - **Accepted:** 30/07/2026
Vol: 13.17
DOI: 10.66104/2691fa20
Pages: 1-25

GALIAZZI, Maria do Carmo; GONÇALVES, Fábio Peres. *A educação pela pesquisa como enfoque didático: a experimentação investigativa*. In: MOREIRA, Marco Antonio (org.). *Educação em ciências*. São Paulo: Escrituras, 2004. p. 89-114.

GIORDAN, Marcelo. *O papel dos experimentos no ensino de ciências*. Química Nova na Escola, São Paulo, n. 10, p. 43-49, nov. 1999.

HODSON, D. *Experimento, ensayo e investigación en la enseñanza de la ciencia*. Enseñanza de las Ciencias, v. 12, n. 1, p. 96-104, 1994.

JUNQUEIRA, L. C.; CARNEIRO, J. *Biologia Celular e Molecular*. 9. ed. Rio de Janeiro: Guanabara Koogan, 2012.

KOTZ, John C.; TREICHEL, Paul M.; TOWNSEND, John R. *Química Geral e Reações Químicas*. v. 2. 9. ed. São Paulo: Cengage Learning, 2016.

LIMA, P. N.; GOES, L. F.; FERNANDEZ, C. *Jogando com fórmulas e reações: ludicidade no ensino de Química para explorar a representação molecular no balanceamento químico*. Química Nova na Escola, v. 48, n. 1, p. 13-23, 2025. Disponível em: https://qnesc.sbq.org.br/online/qnesc48_01/04-QS-183-24.pdf. Acesso em: 27 maio 2026.

LOPES, Débora de Oliveira. *Pasta de dente de elefante*. In: LOPES, Débora de Oliveira (org.). *Experimentos práticos de ciências para o ensino médio*. Ponta Grossa: Atena, 2021. cap. 15, p. 151.

MALDANER, Otavio Aloisio. *A formação inicial e continuada de professores de Química: professores pesquisadores*. Ijuí: Unijuí, 2000.

MORAN, José Manuel. *Metodologias ativas para uma aprendizagem mais profunda e transformadora*. In: MORAN, José Manuel; BEHRENS, Marilda Aparecida. *Metodologias ativas e tecnologias digitais na educação*. Porto Alegre: Penso, 2021.

MORAN, José Manuel. *A mediação pedagógica com as tecnologias*. In: BEHRENS, Marilda Aparecida (org.). *Novas tecnologias e mediação pedagógica*. Campinas: Papirus, 2000.

MORIN, Edgar. *A cabeça bem-feita: repensar a reforma, reformar o pensamento*. 22. ed. Rio de Janeiro: Bertrand Brasil, 2015.

MORTIMER, Eduardo Fleury; AMARAL, Luiz Otávio F. *Quanto mais quente melhor: calor e temperatura no ensino de termoquímica*. Química Nova na Escola, n. 7, p.

REMUNOM
ISSN 2178-6925

Received: 29/06/2026 - **Accepted:** 30/07/2026
Vol: 13.17
DOI: 10.66104/2691fa20
Pages: 1-25

30-34, maio 1998. Disponível em: https://qnesc.sbq.org.br/online/qnesc07/aluno.pdf. Acesso em: 26 maio 2026.

NELSON, David L.; COX, Michael M. *Princípios de bioquímica de Lehninger*. 7. ed. Porto Alegre: Artmed, 2019.

OLIVEIRA, João Victor Ataide; SOUZA, Rander Lima de; TEIXEIRA, Antônio Zenon Antunes. *Aprendizagem baseada em projetos em práticas pedagógicas na educação profissional*. Revista Ibero-Americana de Humanidades, Ciências e Educação, *[S. l.]*, v. 9, n. 6, p. 1715-1731, 2023. DOI: 10.51891/rease.v9i6.10242. Disponível em: https://periodicorease.pro.br/rease/article/view/10242. Acesso em: 27 maio 2026.

PEREIRA, Wilma Freire Arriel; TEIXEIRA, Antônio Zenon Antunes. *Da Reforma Pombalina à educação brasileira: permanências, rupturas e atualidade*. Revista Ibero-Americana de Humanidades, Ciências e Educação, *[S. l.]*, v. 12, n. 3, p. 1-14, 2026. DOI: 10.51891/rease.v12i3.24807. Disponível em: https://periodicorease.pro.br/rease/article/view/24807. Acesso em: 28 maio 2026.

PIRES, R. M. M.; VIDIGAL, I. V.; LIMA, T. D. de. *Práticas interdisciplinares para a alfabetização científica e o pensamento sustentável*. Revista Foco, *[S. l.]*, v. 19, n. 1, p. e11185, 2026. DOI: 10.54751/revistafoco.v19n1-008. Disponível em: https://ojs.focopublicacoes.com.br/foco/article/view/11185. Acesso em: 25 maio 2026.

ROCHA, A. M. R. Jorge; GODOI, Glauber Silva; SOUZA CAVALCANTE, Sônia Cristina de; SANTOS, Larissa Lopes dos; ATANÁSIO, Ellen Carolyne de Jesus; SANTOS, João Márlio Dantas Santana. *Catalisadores em ação: a decomposição do peróxido de hidrogênio*. Revista de Ensino de Bioquímica, *[S. l.]*, v. 22, n. 2, p. 108-118, 2024. DOI: 10.16923/reb.v22i2.1081. Disponível em: https://www.bioquimica.org.br/index.php/REB/article/view/1081. Acesso em: 25 maio 2026.

SÁNCHEZ VÁZQUEZ, Adolfo. *Filosofia da práxis*. 2. ed. Rio de Janeiro: Paz e Terra, 1977.

SASSERON, Lúcia Helena; CARVALHO, Anna Maria Pessoa de. *Alfabetização científica: uma revisão bibliográfica*. Investigações em Ensino de Ciências, *[S. l.]*, v.

REMUNOM
ISSN 2178-6925

Received: 29/06/2026 - **Accepted:** 30/07/2026
Vol: 13.17
DOI: 10.66104/2691fa20
Pages: 1-25

16, n. 1, p. 59-77, 2011. Disponível em: https://ienci.if.ufrgs.br/index.php/ienci/article/view/246. Acesso em: 26 maio 2026.

SILVA, J. *Pasta de dente de elefante: química na prática*. Universidade Federal do Paraná (UFPR), Curitiba, 2020. Disponível em: http://www.quimica.ufpr.br/paginas/quimica-na-pratica/wp-content/uploads/sites/35/2020/08/PastaDeDenteDeElefante.pdf. Acesso em: 25 maio 2026.

SILVA, Fernanda Beatriz; FURTADO, Rayne T. Falbota; MONTEIRO, Paula Cavalcante; PRICINOTTO, Gustavo. *Pasta de Dente de Elefante para a explicação do conceito de reações exotérmicas e endotérmicas*. IX Encontro Nacional das Licenciaturas (ENALIC), Lajeado, 2023. Disponível em: https://editorarealize.com.br/editora/anais/enalic/2023/TRABALHO_COMPLETO_EV190_MD3_ID7683_TB1409_26112023124925.pdf. Acesso em: 26 maio 2026.

SOUZA, Gilmara Rodrigues de; ASSUNÇÃO, Hélica Lucivane Silva; MOREIRA, Débora Astoni; SOUZA, José Antonio Rodrigues de. *Pasta de Dente de Elefante com materiais alternativos, baixo custo e aquisição fácil*. Ciclo Revista: Vivências em Ensino e Formação, *[S. l.]*, v. 3, n. 1, 2018. Disponível em: https://ifgoiano.emnuvens.com.br/ciclo/article/view/789. Acesso em: 25 maio 2026.

TEIXEIRA, A. Z. A.; SOUZA, R. L. de. *Enriquecimento de farelo de arroz com aminoácidos essenciais por fermentação*. Revista Contemporânea, *[S. l.]*, v. 5, n. 1, p. e7232, 2025. DOI: 10.56083/RCV5N1-034. Disponível em: https://ojs.revistacontemporanea.com/ojs/index.php/home/article/view/7232. Acesso em: 28 maio 2026.

TORRES, Patricia Lupion. *Laboratório de aprendizagem colaborativa: uma proposta para a educação superior*. Santos: Universitária Leopoldianum, 2004.