

# Analysis of ChatGPT as a tool in chemistry education: exploring the topic of matter and energy

## ABSTRACT

**Ismael Laurindo Costa Junior**  
[ismael@utfpr.edu.br](mailto:ismael@utfpr.edu.br)  
[orcid.org/0000-0001-6295-1619](https://orcid.org/0000-0001-6295-1619)  
Universidade Tecnológica Federal do  
Paraná (UTFPR), Medianeira, Brasil

O *ChatGPT* é uma das ferramentas baseadas em inteligência artificial (IA) com destaque no meio educacional pela popularidade e promessas de praticidade. No Ensino de Química, surge como um atraente recurso para uso em atividades escolares. Diante disso, este artigo propõe a reflexão sobre o uso do *ChatGPT* como recurso didático no estudo do tema Matéria e Energia. Para tanto, foi explorado o potencial dessa ferramenta como interface de pesquisa para definições e resolução de problemas, na perspectiva dos conteúdos mediados na Educação Básica. O estudo é de natureza qualitativa e exploratória e envolveu a elaboração de cinco enunciados formulados a partir do Referencial Curricular para o Ensino Médio do Paraná e três problemas extraídos de um dos livros didáticos disponíveis nas escolas públicas. Tais enunciados e problemas foram inseridos na interface do *ChatGPT-PRO* versão 4.0 e as respostas transcritas, descritas e interpretadas em termos de coerência, assertividade e complexidade a partir de uma fonte bibliográfica do tipo dicionário e a resolução contida livro didático. Os resultados obtidos suscitaram preocupações quanto ao uso do *ChatGPT* de forma autônoma por sujeitos que não detém os conhecimentos para questionar ou analisar as respostas autogeradas pela IA. Foram verificadas informações complexas/confusas envolvendo definições e erros de resolução nos problemas. Diante disso, o uso do *ChatGPT*, pode apresentar aplicações relevantes de auxílio aos estudos, mas por si não produz conhecimentos, apenas informações que requerem revisão e contestação. Nesse cenário, reforça-se a função do professor como mediador da aprendizagem e dos recursos baseados em IA.

**KEYWORDS:** Chatbot; Artificial intelligence; Study tool; Chemistry.

# Análise do ChatGPT como ferramenta no ensino de química: explorando o tema matéria e energia

## RESUMO

O *ChatGPT* é uma das ferramentas baseadas em inteligência artificial (IA) com destaque no meio educacional pela popularidade e promessas de praticidade. No Ensino de Química, surge como um atraente recurso para uso em atividades escolares. Diante disso, este artigo propõe a reflexão sobre o uso do *ChatGPT* como recurso didático no estudo do tema Matéria e Energia. Para tanto, foi explorado o potencial dessa ferramenta como interface de pesquisa para definições e resolução de problemas, na perspectiva dos conteúdos mediados na Educação Básica. O estudo é de natureza qualitativa e exploratória e envolveu a elaboração de cinco enunciados formulados a partir do Referencial Curricular para o Ensino Médio do Paraná e três problemas extraídos de um dos livros didáticos disponíveis nas escolas públicas. Tais enunciados e problemas foram inseridos na interface do *ChatGPT-PRO* versão 4.0 e as respostas transcritas, descritas e interpretadas em termos de coerência, assertividade e complexidade a partir de uma fonte bibliográfica do tipo dicionário e a resolução contida livro didático. Os resultados obtidos suscitaram preocupações quanto ao uso do *ChatGPT* de forma autônoma por sujeitos que não detém os conhecimentos para questionar ou analisar as respostas autogeradas pela IA. Foram verificadas informações complexas/confusas envolvendo definições e erros de resolução nos problemas. Diante disso, o uso do *ChatGPT*, pode apresentar aplicações relevantes de auxílio aos estudos, mas por si não produz conhecimentos, apenas informações que requerem revisão e contestação. Nesse cenário, reforça-se a função do professor como mediador da aprendizagem e dos recursos baseados em IA.

**PALAVRAS-CHAVE:** Chatbot; Inteligência artificial; Ferramenta de estudos; Química.

## INTRODUCTION

Digital technologies have significantly advanced across socioeconomic, cultural, educational, and communicative contexts. In this sense, in a world driven by technological innovation, education must appropriate and coexist within a scenario in which Digital Information and Communication Technologies (DICTs) have come to occupy all spaces, including the classroom itself (Leite, 2022; Melo, Melo & Silvano, 2021; Figueiredo & José, 2022).

The most recent wave in the field of digital technological tools has brought forth Artificial Intelligence (AI). According to Parreira, Lehmann, and Oliveira (2021, p. 979)

[...] AI exists when a machine displays intelligent behavior, that is, it responds appropriately to its environment and acts with a probability of success. Examples include: engaging properly in a conversation; competing in strategic games such as chess and Go; interpreting complex data. In such cases, we are dealing with an AI system, which may be narrow or general.

This technology, therefore, raises expectations as a promising resource capable of profoundly transforming “the way society operates, driving efficiency, innovation, and discovery in a variety of fields. AI applications are already visible in multiple sectors, from medicine to agriculture, and education is no exception” (Oliveira *et al.*, 2023, p. 2).

One of the AI-based tools gaining popularity and attention in the educational context is ChatGPT, launched in 2022, capable of generating convincing sentences by mimicking statistical patterns of language based on a massive database of internet text (Leite, 2022; Stokel-Walker, 2023).

According to Giraffa and Kohls-Santos (2023, p. 126), it is:

[...] a specific version of the GPT (Generative Pre-trained Transformer) language model developed by OpenAI. GPT is an artificial intelligence model that uses a neural network architecture known as Transformer to generate responses and interact with text in a natural manner.

From Leite’s perspective (2023, p. 916), “ChatGPT, a chatbot, is one of those machines that interact with people, being a variant of the GPT artificial intelligence language model.” Initially, this tool was accessible through an account created on the developer’s website, OpenAI, and is essentially composed of a text box in which users write their queries. Thus, no programming knowledge is required. Currently, since 2024, a limited free version and a subscription-based AI app version with additional functionalities are available (OpenAI, 2024).

Gualberto Neto (2023) emphasizes that ChatGPT is a versatile and effective tool with various applications, which has gained acceptance due to its simplicity of interaction with users. In this context, it represents a promising and innovative addition to the repertoire of strategies that can contribute to teaching and learning processes (Oliveira *et al.*, 2023).

Among the main educational uses of ChatGPT are text writing, summarizing assignments, researching various topics, answering questions, preparing lesson plans, translation, and many other possibilities, depending on the user's creativity (Leite, 2023; Stokel-Walker, 2023; Gualberto Neto, 2023). In terms of quality, Graham (2023) highlights that the chatbot was capable of producing research

summaries with content of such quality that researchers were unable to identify that it had been written by AI.

Given this, many discussions have accompanied the emergence of chatbots such as ChatGPT. The main concerns involve issues of authorship and the use of these tools to generate responses in place of users (Stokel-Walker, 2023; Tate *et al.*, 2022; Leite, 2023; Escalante, Pack & Barrett, 2023). In this regard, just as neither the teacher nor technology can transfer knowledge by themselves, ChatGPT and other DICTs cannot replace the constructive processes that learners must undertake to acquire information and reorganize it cognitively in order to truly appropriate such knowledge (Zittoun *et al.*, 2011).

The field of Exact Sciences primarily encompasses scientific knowledge from well-defined and consolidated disciplines that are recognized as independent sciences, namely Mathematics, Physics, Chemistry, and Computer Science (Garcia & Gomes, 2022). Historically, this knowledge has been curricularized into subjects and courses of the same names across various educational levels and formats. These areas are also known for being those in which students face the greatest learning challenges (Fumes & Antônio, 2019).

In the context of Chemistry Education, this scenario results in students' low interest and poor academic performance, which demands the search for resources and strategies capable of enhancing performance and conceptual understanding in this field (Moura Júnior *et al.*, 2020). As such,

[...] technology can be a tool to make content more engaging and relevant to students, providing opportunities for exploration and problem-solving in a more autonomous way. It can facilitate the understanding of abstract concepts, offer practice and immediate feedback opportunities, and engage students through playful and interactive approaches" (Oliveira *et al.*, 2023, p. 5–6).

With the advent and accessibility of AI via chatbots, students now have an additional type of DICT available to support their studies. According to Borba and Balbino Junior (2023, p. 147–148), despite the constant evolution of tools such as ChatGPT, generative AI presents limitations:

[...] it depends on large amounts of data to learn and generate content, and it does not always produce perfect or unbiased results. Therefore, although it is a promising technology, its development and application still require careful and critical monitoring. Nevertheless, the generative nature of these systems raises concerns about their reliability.

Aiming **to contribute to the exploration of ChatGPT as a didactic** resource for studying the topic of Matter and Energy from the perspective of Basic Education students, this article proposes an analysis of this chatbot regarding its potential as a research interface for basic definitions, problem solving, and the evaluation of the answers it provides.

## METHODOLOGICAL APPROACH

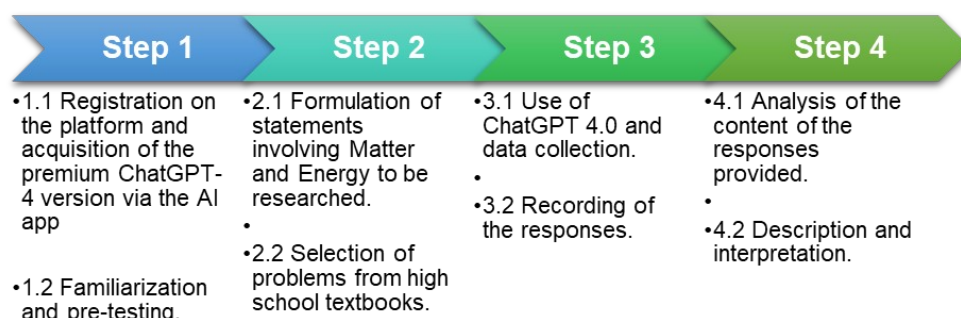
The methodology of a research study "[...] simultaneously includes the theory of the approach (the method), the instruments for the operationalization of knowledge (the techniques), and the creativity of the researcher (their experience, personal capacity, and sensitivity)" (Minayo, 2009, p. 14). Accordingly, regarding its

approach, the research conducted is classified as qualitative in nature and involved the technical procedures of data collection, description, and interpretation.

In terms of its purpose, this is an applied research project, motivated by the need for “[...] the acquisition of knowledge aimed at application in a specific situation” (Gil, 2019, p. 26), which, in this case, was to investigate the potential and limitations of the ChatGPT tool in defining concepts, answering questions, and solving problems related to Matter and Energy, in order to contribute (or not) to the construction of knowledge. Figure 1 summarizes the stages of the study.

**Figure 1**

*Research stages*



Source: Author's own elaboration (2024).

In this study, version 4.0 of ChatGPT-PRO, available as an AI App, was used. In Stage 1, the researcher registered on the OpenAI digital platform to access the tool and purchase the subscription plan. Subsequently, preliminary tests were conducted to become familiar with the tool by requesting information related to the AI's self-description and how it could be used for study purposes (Table 1).

In Stage 2, the Referential Curriculum for High School Education of the State of Paraná (Paraná, 2021) was consulted, specifically the section addressing the specific competencies of the area of Natural Sciences and the Chemistry curriculum component. From this document, knowledge objects and content relevant to the topic Matter and Energy were identified. Based on the information obtained, key terms were selected to formulate prompts submitted to the chatbot (Table 1).

In addition, aiming to explore the ChatGPT's ability to solve learning activities, three problems were selected from the high school textbook “Ser Protagonista: Ciências da Natureza e suas tecnologias” (Zamboni & Bezerra, 2020).

**Table 1**

*Prompts used in the conceptual research*

Stage	Knowledge Object	Prompts
1	-	1.1 Introduce yourself.
		1.2 How can I make good use of you for studying?
		1.3 Can you help me study the topic Matter and Energy? How?
2	Composition of Matter	2.1 What is matter?
		2.2 What are the properties of matter?

Conservation of Energy	2.3 What is energy?
	2.4 How is energy conserved in the universe?
Transformation of Matter	2.5 What is the role of energy in the transformation of matter?

Source: Author's own work (2024).

The selection was based on the fact that this textbook was among the options available to public schools in Paraná through the National Textbook Program (Programa Nacional do Livro Didático – PNLD) in 2021 (Figure 2).

## Figure 2

*Problems extracted from the textbook “Ser Protagonista: Ciências da Natureza e suas tecnologias”*

### a) Problem 1

1. The famous law by French chemist Antoine Lavoisier — “In nature, nothing is created, nothing is lost, everything is transformed” — refers to the conservation of matter. Do you know of another physical quantity that behaves in a similar way? If so, which one?

### b) Problem 2

2. What is the origin of the chemical elements in the materials that surround us and of most of the energy we consume?

### c) Problem 3

1. In a laboratory, a student decides to analyze the thermal properties of a metal block. For this purpose, a 200 g metal block, made of an unknown material, received 1000 cal and experienced a temperature increase from 20 °C to 40 °C. Considering these conditions, do the following:

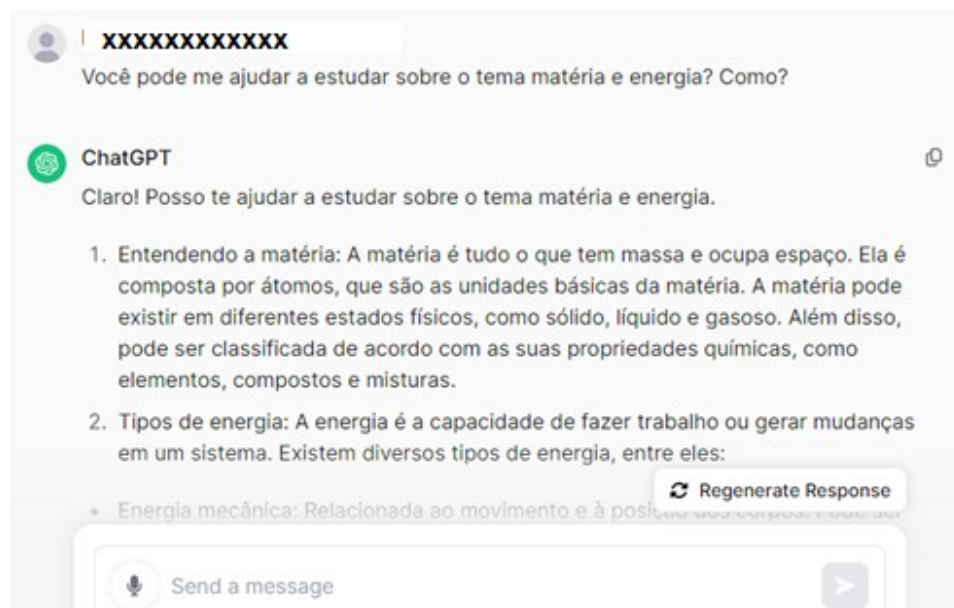
- Determine the heat capacity of the block.
- Define the specific heat of the material the block is made of.
- Calculate the amount of heat needed to raise the temperature of this block from 20 °C to 350 °C.

Source: Zamboni & Bezerra (2020, pp. 14, 137).

Stage 3 involved data collection. The prompts created in Stage 2 were individually entered into the ChatGPT dialogue box, with a new session initiated for each query. The data was recorded through screen captures (screenshots) (Figure 3) and by copying the textual responses using the "copy" function provided by the chatbot itself.

**Figure 3**

*Example of a screenshot and representation of the ChatGPT user interface*



Source: OpenAI (2024).

Finally, in Stage 4, the content provided by the AI for each prompt was analyzed and described. The conceptual information was compared with the definitions found in the Dicionário de Química (Barbosa, 2007), a supplementary reference work intended for chemistry study and research by Brazilian students. The responses to the problems were assessed for accuracy, coherence, and overall quality.

## RESULTS AND DISCUSSION

To present the results, the data produced in the research were organized into sections. The first section is dedicated to the analysis of the information provided in Step 1, which focuses on initial familiarization and exploration. The second section presents the data from Step 2, concerning the responses to the prompts used to investigate information about Matter and Energy, based on the knowledge objects contained in the High School Curriculum Reference for Paraná. The third set of data addresses the answers provided by the AI to the problems extracted from the textbook "Ser Protagonista: Ciências da Natureza e suas tecnologias" (Zamboni & Bezerra, 2020).

### INFORMATION OBTAINED DURING THE INITIAL FAMILIARIZATION AND EXPLORATION STAGE OF THE RESEARCH

Table 2 presents the transcribed responses from the chatbot to the initial inquiry carried out in Step 1 of the research. The first piece of information collected from ChatGPT was its self-definition, prompted by statement 1.1, in which the AI was asked to introduce itself. It can be observed that the response includes a brief



description of the tool in a friendly and inviting tone. Additionally, it briefly outlines its potential and possibilities to be explored by the user.

**Table 2**

*Conceptual research prompts used*

Prompt	Response
1.1	Hello! I'm the AI App, a virtual assistant designed to help and answer your questions. I'm here to provide information, guidance, and solutions to your doubts or problems. As an artificial intelligence-based assistant, I can help you with a wide variety of topics—from offering general information to assisting with specific tasks. Feel free to ask me anything, and I'll do my best to help you! (OpenAI, 2024).
1.2	As your virtual assistant, I can be very useful for your studies in several ways. Here are some suggestions on how you can make good use of me: 1. Explaining concepts: [...]. 2. Language practice: [...]. 3. Homework assistance: [...]. 4. Source of information: [...]. 5. Study organization: [...]. 6. Test preparation: [...]. 7. Constructive feedback: [...]. 8. Discussion and deepening: [...]. Keep in mind that my support follows ethical guidelines, and I do not endorse practices such as plagiarism or academic dishonesty. It's important that you use the information I provide as a starting point for your own learning and critical thinking. (OpenAI, 2024).
1.3	Sure! I can help you study the topic of matter and energy.

Source: Author's own (2024).

Prompt 1.2 was inserted with the intention of identifying the ways in which the AI integrated with ChatGPT would present itself as available to assist users in their studies. The answer provided is impressive in terms of quality and promptness, as evidenced by the excerpt: “[...] I can be very helpful in your studies in several ways. Here are some suggestions on how you can make good use of me [...]” (OpenAI, 2024).

In this direction, the chatbot lists and details eight applications (Table 2), with variety and complexity, in which it offers to contribute to the user's studies. We highlight option 1, whose purpose was “Concept Explanation: If you are having trouble understanding a specific concept, just ask and I can provide a detailed or simplified explanation according to your need” (OpenAI, 2024). This self-suggested use aligns with the aim of this research, which is to analyze ChatGPT's contributions to researching definitions and basic information about Matter and Energy.

Given the numerous possibilities ChatGPT offers and its accessibility, it is necessary to conduct studies on the use of this tool in the field of education, as many students may resort to it to enhance their learning in subjects where they encounter difficulties—such as Chemistry, in which students often struggle to relate certain concepts. Even though ChatGPT may enhance teaching and learning processes, it is essential to verify the coherence of the responses obtained in the chat for student use (Eugenio *et al.*, 2023, p. 463).

Finally, the study methods self-indicated by the AI itself are consistent with the possibilities highlighted by Guimarães *et al.* (2023), which concern research support and answering questions.



Prompt 1.3 guided the exploration of the tool toward the topic of interest: the study of Matter and Energy. The language used in this prompt was adjusted to reflect that of a Basic Education student requesting assistance from the AI for a school research assignment, through the question: “Can you help me study the topic of Matter and Energy? How?”. The excerpt provided by ChatGPT maintained a “humanized” tone and directly listed the main concepts and definitions on the topic (Table 2).

Moreover, it was observed that the AI demonstrated a “concern” for the user regarding the adequacy of the information provided and a “readiness” for further exploration, as seen in the final part of the response: “[...] I hope this information helps you better understand the topic of matter and energy. If you have a specific question or want to go deeper into any aspect, just ask me!” (OpenAI, 2024).

According to Oliveira, Siqueira & Almeida (2023, p. 112), the ability of an AI-based tool to imitate a human being without being exposed is considered a marker of its efficiency. Nevertheless, according to the same authors, “[...] in the experiments conducted with ChatGPT, the agent always states that it is a language model that does not possess opinions, judgments, or emotions, thus avoiding humanized projections”.

However, based on the initial analysis presented here, **it can be considered that the ChatGPT chatbot encouraged the user to interact with the tool, even offering the possibility of reworking the content with greater or lesser complexity**, in addition to suggesting a “concern” with the quality of the response, as highlighted in the previously mentioned excerpt: “I hope this information helps you better understand the topic [...]” (OpenAI, 2024). Once this first stage of familiarization was completed, the prompts aimed at obtaining definitions and concepts for the study of the topic Matter and Energy using AI as a support tool were then introduced.

#### DEFINITIONS AND INFORMATION ON MATTER AND ENERGY PROVIDED BY CHATGPT

According to Milaré & Alves Filho (2010, p. 51), “concepts such as Energy, Matter, and Transformation have a unifying character across the various fields of Science and structure the knowledge necessary for the development of scientific thinking.” Thus, understanding these concepts contributes to interpreting various everyday phenomena.

According to Silva & Simões Neto (2022), despite differences in structure, conception, and implementation at the political-ideological level, the National Common Curricular Base (BNCC), with regard to the area of Natural Sciences and its technologies, emphasizes the importance of studying content related to Matter and Energy, with a focus on conceptual knowledge. This focus aims to enable students to articulate these concepts with the world around them. In this context, the exploration proposed in this research regarding the use of ChatGPT as a didactic resource for the study of Matter and Energy supports this perspective.

Table 3 presents the transcriptions of the responses to the prompts obtained in the research stage focused on definitions and concepts related to Matter and Energy with ChatGPT.

**Table 3**

*Transcriptions of data from the research stage on definitions involving Matter and Energy*

Prompt	Response
2.1	In science, matter is defined as any substance that has mass and occupies space in the universe. In other words, it is everything made up of atoms. Matter can exist in different physical states, such as solid, liquid, and gas, depending on the organization and movement of its particles. There are two main types of matter: ordinary matter and dark matter. Ordinary matter is composed of subatomic particles such as protons, neutrons, and electrons, which form atoms. Dark matter, on the other hand, is a form of matter that does not interact with light or other forms of electromagnetic radiation and is therefore invisible to our detection instruments. Matter is the basic building block of physical existence throughout the universe and is studied in various scientific disciplines such as physics, chemistry, and astronomy. Studying matter allows us to understand the properties and behaviors of the various substances that surround us. (OpenAI, 2024)
2.2	The properties of matter can be divided into two main categories: physical properties and chemical properties. Physical properties: Mass: the amount of matter present in an object, measured in kilograms (kg). Volume: the space occupied by an object, measured in liters (L) or cubic meters (m <sup>3</sup> ). Density: the relationship between the mass and volume of an object, expressed in kg/m <sup>3</sup> . Physical state: matter can exist in the solid, liquid, or gaseous state, depending on the attractive forces between its particles. Melting point: the temperature at which a substance changes from solid to liquid. Boiling point: the temperature at which a substance changes from liquid to gas. Thermal and electrical conductivity: some substances conduct heat and electricity better than others. Chemical properties: Combustibility: the ability of a substance to burn or react with oxygen. Reactivity: indicates how easily a substance reacts chemically with other substances. Acidity or basicity: some substances are acidic, others basic (or alkaline), depending on their pH and ability to donate or receive hydrogen ions. Corrosiveness: the ability of some substances to corrode or oxidize other substances. Stability: indicates the ability of a substance to remain unchanged under certain conditions. These are just some of the properties of matter, and each substance has its own specific characteristics. Studying these properties helps us understand how matter behaves and interacts under different circumstances. (OpenAI, 2024)
2.3	Energy is a physical quantity related to the ability to perform work. It is a fundamental property of the universe and is present in all forms of matter. Energy can be found in various forms, such as kinetic energy, potential energy, thermal energy, electrical energy, and chemical energy, among others. Kinetic energy is associated with the motion of an object—the greater its speed and mass, the greater its kinetic energy. For example, a moving car has kinetic energy due to its velocity. Potential energy is related to the position of an object relative to a reference point. A common example is gravitational potential energy, which depends on an object's height relative to the Earth's surface. Thermal energy is energy related to the temperature of an object. It is associated with the movement of particles that make up matter. The faster and more agitated the movement of these particles, the greater the thermal energy. Electrical energy is the energy associated with moving electric charges. It is widely used in our daily lives to power electronic devices and electrical systems. Chemical energy is related to chemical reactions and the energy stored in the bonds between atoms in a substance.

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For example, energy is released when gasoline burns in an engine, producing kinetic energy. In addition to these specific forms of energy, there is also the law of conservation of energy, which states that the total energy in an isolated system remains constant—that is, energy cannot be created or destroyed, only converted from one form to another. Understanding and studying energy is fundamental in various fields of science, such as physics, chemistry, biology, and engineering. Energy plays an essential role in all natural and technological processes, driving the functioning of our world. (OpenAI, 2024)

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- 2.4 Energy is conserved in the universe according to the law of conservation of energy, also known as the principle of conservation of energy. This law states that the total energy in an isolated system remains constant over time. This means that energy cannot be created or destroyed, only converted from one form to another. In an isolated system, energy can change form—for example, from kinetic energy to potential energy, or among other types, such as thermal to electrical energy. For example, when an object is dropped from a height, its gravitational potential energy is converted into kinetic energy as it falls. Upon hitting the ground, the kinetic energy is dissipated in the form of heat and sound. This conservation of energy is based on the broader principle that the total amount of energy in the universe remains constant. The law of energy conservation has been confirmed by countless observations and experiments over the years and is considered one of the fundamental laws of physics. However, it is important to note that although energy is conserved in the universe as a whole, on a local scale, such as on Earth, energy can be transformed from one form to another but never "disappears" completely. There will always be energy losses in the form of heat dissipation or other forms of energy dispersion, but the total energy in an isolated system remains constant. (OpenAI, 2024)
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Source: Author's own work (2024).

The first prompt (2.1) used in the consultation with ChatGPT sought to obtain an answer to the question: "What is matter?" (Table 3). According to the AI, "In science, matter is defined as any substance that has mass and occupies space in the universe. In other words, it is everything made up of atoms" (OpenAI, 2024). The first part of this definition is consistent with that found in teaching manuals and general textbooks, including a clear indication that the AI understood that it concerns the concept within the field of science. The *Dicionário de Química* defines matter as "[...] any solid, liquid, or gaseous substance that occupies space" (Barbosa, 2007, p. 230).

However, the immediate use of the term "atom" as a basic unit requires a more advanced level of understanding, such as that expected of a student beyond basic education. In curricular terms, the study, presentation, and definition of the atom as a fundamental unit comes after the initial topic dealing with definitions of Matter and Energy from a more general perspective.

The same complexity is observed in the excerpt where the AI states that "there are two main types of matter: ordinary matter and dark matter" (OpenAI, 2024). Although the mention of dark matter is relevant information, from a school-based perspective this topic is not addressed, mainly due to the scientific uncertainties surrounding it (Teixeira & Souza, 2022). However, in the following excerpt—"matter is the basic building block of physical existence throughout the universe and is studied in various scientific disciplines such as physics, chemistry, and

astronomy” (OpenAI, 2024)—ChatGPT offers a complementary and differentiated definition from that given in the first part of the response, which may be considered positive in terms of completeness and the interdisciplinary perspective of the concept of Matter.

For prompt 2.2, “What are the properties of matter?”, the initial information obtained (Table 3) was that “[...] the properties of matter can be divided into two main categories: physical properties and chemical properties” (OpenAI, 2024). However, the definition commonly found in textbooks initially presents a division of properties into general and specific, or intensive and extensive. Barbosa (2007, p. 280) states:

**Specific properties of matter** – Those that serve to identify and differentiate pure substances from mixtures [...].

**General properties of matter** – Those that can be observed in any type of matter.

The organization presented by ChatGPT may cause confusion as it blends general physical properties with specific physical properties without mentioning this distinction, which may be inconsistent. It would be appropriate to clarify that general properties are common to and observable in any type of matter, such as mass, volume, and density, as highlighted by Barbosa (2007). In this regard, it would be relevant to add that specific physical properties characterize a given substance, such as melting and boiling points.

Additionally, the chatbot lists “physical state” as one of the properties of matter and subsequently presents specific physical properties that characterize a substance, as seen in the excerpt:

Physical properties: Mass: [...]. Volume: [...]. Density: [...]. Physical state: matter can exist in the solid, liquid, or gaseous state, depending on the attractive forces between its particles. Melting point: [...]. Boiling point: [...]. Thermal and electrical conductivity: [...] (OpenAI, 2024).

Brown *et al.* (2016) defines physical state as a way of classifying matter based on its aggregation form, which is not necessarily a property. Thus, it is noted that, for this prompt, the information provided requires review by the user before any academic or school-related use.

Through prompt 2.3, “What is energy?”, the intention was to obtain the definition of energy provided by ChatGPT. According to the AI:

Energy is a physical quantity related to the capacity to perform work. It is a fundamental property of the universe and is present in all forms of manifestation of matter (OpenAI, 2024).

In this excerpt, one can recognize the basic definition, in which there is a relation to the performance of work. Therefore, the definition presented by the AI is consistent with Barbosa (2007, p. 128), who defines energy as a “property of a system that allows it to perform work.” Another relevant point is the coexistence between matter and energy, which allows the user to associate energy with the processes of transformation of matter.

After presenting the definition, the text generated by ChatGPT provides a brief description of the main types of energy, as well as examples in which they are present, in order to facilitate the reader’s understanding (Table 3). In the final

excerpt, ChatGPT emphasizes that energy “[...] cannot be created or destroyed, only converted from one form to another” (OpenAI, 2024), and adds that “energy plays an essential role in all natural and technological processes, driving the functioning of our world” (OpenAI, 2024). This passage expresses what Barbosa (2007, p. 128) defines as the “first law of thermodynamics”.

Comparatively, the response provided by ChatGPT to prompt 2.3 was more well-constructed than the one presented for prompt 2.1. A possible explanation for this may lie in the way the topic of energy is addressed in terms of definition and applications, which facilitates the understanding of the subject. On the other hand, the understanding of matter and its properties often involves more abstract and complex reasoning, which may justify the earlier mention of dark matter.

Although the conservation of energy was already mentioned by the AI in response to prompt 2.3, the topic was addressed again through the next prompt: “2.4 How is energy conserved in the universe?” According to the chatbot:

Energy is conserved in the universe according to the law of conservation of energy, also known as the principle of conservation of energy. This law states that the total energy in an isolated system remains constant over time (OpenAI, 2024).

It can be observed that, from the formulation of a specific question on the subject, the response generated by the tool was more detailed and includes the principle of energy conservation, which establishes that “[...] energy cannot be created or destroyed, only transformed” (BARBOSA, 2007, p. 277).

The remainder of the text generated by ChatGPT presents examples through which the topic is made more comprehensible to the reader (Table 3), including a variation in language between formal definitions in the initial part of the response and expressions closer to common sense, as can be seen in the sentence “[...] energy can be converted from one form to another, but it never ‘disappears’ completely” (OpenAI, 2024).

The last conceptual statement researched (2.5) sought to obtain a response from the chatbot to the question: “What is the role of energy in the transformation of matter?”. The text produced by the AI presented the following definitions in the initial excerpt: “Energy plays a fundamental role in the transformation of matter. Energy is necessary for chemical reactions that lead to the transformation of substances” (OpenAI, 2024). The information provided is incomplete and contains gaps similar to those observed in statement 2.2. In the excerpt, there is a predominance of the matter-energy relationship in chemical reactions, almost hegemonically.

The transformation of matter can be considered from physical and chemical perspectives. The first refers to phenomena related to states of matter and their changes, without alteration of the basic unit that typifies the substance. The second encompasses chemical reactions that result in the modification and transformation of one substance into others through the reorganization of matter (Brown *et al.*, 2016; Barbosa, 2007). Thus, this differentiation is more consistent with what is intended to support Basic Education students.

Advancing the reading of the response to statement 2.5 (Table 3), secondarily, the AI presents the matter-energy relationship in phenomena of physical state changes, as in the segment: “[...] moreover, energy is also involved in changes of

the physical state of matter, such as melting and vaporization" (OpenAI, 2024). Similarly, to what was observed in statements 2.3 and 2.4, the remaining information corresponds to examples and contextualization of the core definitions of the question for better user understanding.

In general terms, **the definitions provided by ChatGPT were robust and approached the information contained in the Chemistry Dictionary used as a bibliographic reference.** However, **some responses were complex, incomplete, and partially coherent**, considering its use as a research source in studies.

Regarding this, Leite (2023, p. 921) highlights that "when analyzing ChatGPT's answers, caution is necessary, as some definitions may lead to distorted interpretations by students." This reinforces the need for supervised and teacher-guided use, showing that AI-generated information is subject to errors and may not be the most reliable source for consultation. According to Albuquerque & Dores (2023, p. 10-11), "[...] responses are associated with commands, i.e., poorly formulated commands can generate superficial answers".

#### SOLUTIONS PRESENTED BY CHATGPT FOR PROBLEMS EXTRACTED FROM TEXTBOOKS

In addition to using ChatGPT as a research tool, the answers provided to three problems on the theme Matter and Energy taken from the new High School textbook "Ser Protagonista: Ciências da Natureza e suas tecnologias" (Zamboni & Bezerra, 2020) (Table 4) were evaluated.

Problem 1 highlights the conservation of matter through Lavoisier's Law and seeks to make the reader relate this principle to other quantities (Figure 2). The statement was fully entered into the chatbot, which produced the following answer: "Yes, in addition to the conservation of matter, there is also the conservation of energy" (OpenAI, 2024). In this excerpt, it is possible to verify that ChatGPT provided the correct answer to the request. Furthermore, a justification was given that supports the mention of Energy as a conserved quantity similar to Matter, through the assertion that "this idea is fundamental in physics and is known as the principle of conservation of energy" (OpenAI, 2024). Therefore, the AI-generated answer is coherent with the definitions in the Chemistry Dictionary (Barbosa, 2007).

**Table 4**

*Answers to problems extracted from textbooks*

Problem	Answer
1	Yes, in addition to the conservation of matter, there is also the conservation of energy. According to the principle of conservation of energy, the energy in an isolated system remains constant over time; that is, energy cannot be created or destroyed, only transformed from one form to another. This means that the total amount of energy in a closed system remains the same, regardless of the transformations that occur within it. This idea is fundamental in physics and is known as the principle of conservation of energy (OpenAI, 2024).
2	The chemical elements present in the materials around us and in most of the



energy we consume originate from natural and historical processes. Most chemical elements were formed during the evolution of the universe, beginning with the Big Bang, which occurred approximately 13.8 billion years ago. During the Big Bang, primarily hydrogen and helium atoms were created. As the universe expanded and cooled, stars began to form. In the cores of these stars, nuclear fusion reactions occur, fusing light atomic nuclei such as hydrogen and helium to form heavier elements. These nuclear processes produce elements such as carbon, oxygen, nitrogen, iron, and others. Eventually, these stars reach the end of their lives, undergoing supernovae—powerful explosions that release enormous amounts of energy and disperse heavy chemical elements into space. These elements may recombine to form new stars, planets, and other celestial bodies. Regarding the energy we consume, most of it comes from non-renewable sources such as petroleum, coal, and natural gas. These fossil fuels are formed over millions of years from organic matter, such as the remains of plants and animals. The energy contained in these fossil fuels is released when they are burned. However, it is important to highlight that the use of these fossil fuels significantly contributes to climate change and environmental degradation. Therefore, there is growing interest and investment in renewable and sustainable energy sources, such as solar, wind, and hydroelectric power, which harness natural resources to produce energy without emitting greenhouse gases or causing significant environmental damage (OpenAI, 2024).

- 3 a) To determine the heat capacity of the metal block, we can use the formula:  
 $Q = mc\Delta T$   
 Where:  
 $Q$  is the amount of heat supplied to the block,  
 $m$  is the mass of the block,  
 $c$  is the heat capacity of the block, and  
 $\Delta T$  is the temperature change.  
 In this case, we have:  
 $Q = 1000 \text{ cal}$  (or  $1000 \text{ g}\cdot\text{cal}$ , since  $1 \text{ cal} = 1 \text{ g}\cdot\text{cal}$ )  
 $m = 200 \text{ g}$   
 $\Delta T = 40^\circ\text{C} - 20^\circ\text{C} = 20^\circ\text{C}$   
 Substituting the values into the formula:  
 $1000 \text{ g}\cdot\text{cal} = 200 \text{ g} \cdot c \cdot 20^\circ\text{C}$   
 $c = 1000 \text{ g}\cdot\text{cal} / (200 \text{ g} \cdot 20^\circ\text{C})$   
 $c = 2.5 \text{ g}\cdot\text{cal}/^\circ\text{C}$   
 Therefore, the heat capacity of the metal block is  $2.5 \text{ g}\cdot\text{cal}/^\circ\text{C}$ .  
 b) The specific heat ( $c$ ) of a material is the amount of heat required to raise the temperature of 1 gram of that material by  $1^\circ\text{C}$ . In the case of the metal block, the heat capacity ( $C$ ) was already calculated as  $2.5 \text{ g}\cdot\text{cal}/^\circ\text{C}$  for a mass of  $200 \text{ g}$ . Therefore, to find the specific heat ( $c$ ) of the material, we can use the formula:  
 $c = C/m$   
 Substituting the values:  
 $c = 2.5 \text{ g}\cdot\text{cal}/^\circ\text{C} / 200 \text{ g}$   
 $c \approx 0.0125 \text{ g}\cdot\text{cal}/\text{g}\cdot^\circ\text{C}$   
 Thus, the specific heat of the metal block's material is approximately  $0.0125 \text{ g}\cdot\text{cal}/\text{g}\cdot^\circ\text{C}$ .  
 c) To calculate the amount of heat necessary to raise the block's temperature from  $20^\circ\text{C}$  to  $350^\circ\text{C}$ , we can use the heat capacity formula again:  
 $Q = mc\Delta T$   
 Where:  
 $Q$  is the amount of heat,



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m is the mass of the block,  
c is the specific heat of the material, and  
 $\Delta T$  is the temperature change.

In this case, we have:

$$m = 200 \text{ g}$$

$$c \approx 0.0125 \text{ g.cal/g.}^{\circ}\text{C}$$

$$\Delta T = 350^{\circ}\text{C} - 20^{\circ}\text{C} = 330^{\circ}\text{C}$$

Substituting the values into the formula:

$$Q = 200 \text{ g} * 0.0125 \text{ g.cal/g.}^{\circ}\text{C} * 330^{\circ}\text{C}$$

$$Q \approx 825 \text{ g.cal}$$

Therefore, the amount of heat required to raise the temperature of the block from  $20^{\circ}\text{C}$  to  $350^{\circ}\text{C}$  is approximately 825 g.cal (OpenAI, 2024).

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Source: Author's own (2024).

In Problem 2, the ChatGPT tool was asked to explain the origin of the chemical elements that make up the materials surrounding us and the energy currently available (Figure 2). In general terms, the expected answer, considering the level of a Basic Education student, should include the principle of conservation of Matter and Energy, relating these processes to the universe's origin event (the Big Bang).

The text provided by the AI showed fragmentation, as previously highlighted in the conceptual statements investigated earlier. In the initial excerpt, there was an exclusive focus on the origin of the chemical elements, as shown below:

The chemical elements present in the materials around us and in most of the energy we consume originate from natural and historical processes. Most chemical elements were formed during the evolution of the universe, starting with the Big Bang, which occurred approximately 13.8 billion years ago. During the Big Bang, primarily hydrogen and helium atoms were created (OpenAI, 2024).

Although coherent in terms of fundamentals, the response deepens this origin from the perspective of nucleosynthesis phenomena and fails to mention the conservative view that many of these elements formed at that time are part of the matter composing the current universe.

Regarding the origin of Energy, according to ChatGPT,

[...] most of the energy we consume comes from non-renewable sources, such as petroleum, coal, and natural gas. These fossil fuels are formed over millions of years from organic matter, such as plant and animal remain. The energy contained in these fossil fuels is released when they are burned (OpenAI, 2024).

Similarly, to what was observed regarding the origin of chemical elements, the AI does not revisit the conservation principle. Thus, it does not acknowledge that, like matter, energy also originally existed primordially, and what we have today is a fraction converted into different forms. The final part of the response generated moves on to the environmental implications of fossil fuel use and the demand for renewable energies, which, although relevant, is not consistent with the problem's objective of encouraging students to reflect on the principle of conservation of Matter and Energy.

Finally, in Problem 3, the objective was to explore the capacity to solve numerical questions involving mathematical operations commonly related to studies on Matter and Energy (Figure 2). The problem inserted into the ChatGPT

research interface presented a statement contextualizing the data and information simulating an experimental procedure and subsequently requesting calculations of some parameters.

Initially, it is noteworthy that the AI was able to interpret the statement and use the data provided (Table 4). Furthermore, in each resolution, it detailed the necessary mathematical algorithm, informing the user of each variable required for the operation, as in the following example:

To determine the heat capacity of the metal block, we can use the formula:

$$Q = m \cdot c \cdot \Delta T$$

Where:

Q is the amount of heat supplied to the block,

m is the mass of the block,

c is the heat capacity of the block, and

$\Delta T$  is the temperature change" (OpenAI, 2024).

The instructional manner in which the chatbot guided the step-by-step process to obtain the answers was a very positive point, as it allowed the reader to understand the entire path taken to solve the problem. However, when confronted with the answer key contained in the textbook from which the problem was taken, inconsistencies were found (Figure 4).

The data required for item a) of the problem were correctly selected by the AI, which is confirmed by comparing Table 4 and Figure 4. However, the question requested the heat capacity for the 200 g block, a fact that the tool did not consider and processed the calculation using the formula  $Q = m \cdot c \cdot \Delta T$ , thereby obtaining the heat capacity per gram of the block, providing as a response 2.5 g.cal/°C. This data actually corresponds to the specific heat property of the material.

**Figure 4**

*Answer key for Problem 3 provided by the textbook*

**Atividades (página 137)**

1. a) Dados do problema: 
$$\begin{cases} m = 200 \text{ g} \\ Q = 1000 \text{ cal} \\ \Delta T = 20 \text{ }^{\circ}\text{C} \end{cases}$$

A capacidade pode ser obtida pela razão da quantidade de calor fornecida ao corpo pela variação de temperatura que ele sofre. Assim, temos:

$$C = \frac{Q}{\Delta T} \Rightarrow C = \frac{1000}{20} \Rightarrow C = 50 \text{ cal/}^{\circ}\text{C}.$$

b) Isolando o calor específico na equação fundamental da calorimetria e substituindo nela os dados do problema, obtemos:

$$c = \frac{Q}{m \cdot \Delta T} \Rightarrow c = \frac{1000}{200 \cdot 20} \Rightarrow c = 0,25 \text{ cal/g} \cdot ^{\circ}\text{C}.$$

c) Basta aplicar a equação do calor, considerando que a temperatura variou de 20 °C para 350 °C:

$$Q = m \cdot c \cdot \Delta T \Rightarrow Q = 200 \cdot 0,25 \cdot (350 - 20) \Rightarrow Q = 200 \cdot 0,25 \cdot 330 \Rightarrow Q = 16\,500 \text{ cal}.$$

Source: Zamboni & Bezerra (2020, pp. 14, 251)

Thus, **despite the correct selection of data, ChatGPT did not “understand” the necessary calculation, producing an incorrect answer.** The same error is repeated in items b and c, where the answers also differ from the answer key. Therefore, it can be considered that the use of the tool was unsatisfactory for problems involving numerical operations. According to Eugenio *et al.* (2023, p. 468),

[...] it is observed that the chat is successful in conceptualizing problems, that is, it correctly identifies the nature of the question in most cases. However, in numerical questions, ChatGPT's success is low in generating an appropriate strategy for resolution compared to non-numerical questions.

In the field of mathematics, Sant'ana, Sant'ana & Sant'ana (2023, p. 83) conducted a study in which problems involving operations were proposed in the context of the tool's use by future teachers. According to the authors, inconsistencies and incorrect answers were found in the information produced by ChatGPT. Furthermore, they highlighted that “it is also necessary to proceed in a way to refine the prompt; that is, the clearer and more precise the request, the better the response will be. In other words, the protocol for submitting prompts is fundamental for a good reply”.

## FINAL CONSIDERATIONS

The emergence of AI-based technologies has advanced greatly across all segments of society. The educational sphere is one of the fields where many debates about the use of these resources have arisen, mainly due to the discourse of practicality, speed, and assistance to students in their studies. In light of this, this fact was explored in this article through the analysis of statements and problems on the topic of Matter and Energy, from the perspective of this content in the Paraná State High School Curriculum Framework for the Chemistry subject.

Based on the observations made and the information produced, it can be considered that the use of ChatGPT was partially adequate as a research resource for statements seeking definitions. However, for the solution of problems involving operations, numerical interpretations, or existence conditions, the results were inconsistent and produced incorrect answers.

Therefore, concerns must be raised regarding the autonomous use of ChatGPT by people who lack the knowledge to question or analyze the AI-generated responses — which, in the context proposed here, are Basic Education students. In some circumstances, the chatbot has been regarded as having the same relevance as the teacher in the process of knowledge production and instruction, which does not seem consistent, based on the data obtained in this study and other works already available in the current literature on the use of resources like ChatGPT in Education.

Based on the results verified for theoretical statements and numerical problems, it can be inferred that learning and acquiring knowledge about Matter and Energy in Chemistry Education does not rely solely on the use of a friendly and easily understandable language but largely on the cognitive effort exercised by the

subject to conceptually and logically appropriate the conditions of existence that satisfy a phenomenon under investigation.

Thus, **the use of resources such as ChatGPT may present relevant applications in terms of study assistance, but by itself it does not produce knowledge**—only information that requires review and contestation. It is therefore suggested that its use be conscious, supervised, and mainly that the user be instructed to formulate search statements adequately so as to avoid producing incorrect, superficial, or incomplete and overly complex information.

## REFERENCES

- Albuquerque, J. M. & Dores, J. L. R. (2023). Uso da inteligência artificial no ensino de física: potencialidades e desafios. *Caminhos da educação diálogos culturas e diversidades*, 5(3), 1-14.  
<https://doi.org/10.26694/caedu.v5i3.4657>
- Barbosa, A. L. (2007). *Dicionário de Química*. Goiania, GO: AB Editora.
- Brown, T. L., Lemay Jr., H. E., Bursten, B. E., Murphy, C. J., Woodward, P. M & Stoltzfus, M. W. (2016). *Química: a ciência central*, 13 ed. São Paulo: Pearson Education do Brasil.
- Escalante, J., Pack, A. & Barrett, A. (2023). AI-generated feedback on writing: insights into efficacy and ENL student preference. *International Journal of Educational Technology in Higher Education*, 20,57.  
<https://doi.org/10.1186/s41239-023-00425-2>
- Eugenio, I. D., Silva, L. A. N., Santos, C. M. & Gibin, G. B. (2023). Inteligência artificial frente a resolução de exercícios de química: um estudo exploratório com o ChatGPT. *Colloquium Humanarum*, 20(1), 461-476.  
<https://journal.unoeste.br/index.php/ch/article/view/4786>
- Figueredo, G. L.; José, W. D. (2022). Estudo bibliográfico sobre tecnologias digitais no ensino de ciências da Educação de Jovens e Adultos: possibilidades do conectivismo na perspectiva dialógico-problematizadora. *ACTIO: Docência em Ciências*, 7(3), 1-23. <http://dx.doi.org/10.3895/actio.v7n3.15221>
- Fumes, D. R. & Antonio, A. J. (2019). A adequação do ensino das ciências exatas para um modelo pedagógico contemporâneo. *Revista Satélite*, 1(1), 8-15.  
<https://faculdadegalileu.com.br/revistasatelite/images/1.pdf>
- Garcia, L. M. L. S. & Gomes, R. S. (2022). Causas da evasão em cursos de ciências exatas: uma revisão da produção acadêmica, *Revista Educar Mais*. 6(1), 937-957. <https://doi.org/10.15536/reducarmais.6.2022.2970>
- Gil, A. C. (2019). *Como elaborar projetos de pesquisa*. São Paulo: Atlas.
- Gualberto Neto, J. (2023). ChatGPT Como Ferramenta Matemática. *RevistaFT*. 28(128), 31-52. <https://doi.org/10.5281/zenodo.10200731>
- Guimarães, U. A., Brandão, C. A., Daitx, M. A., Dutra, A. F. G. A. & Lopes, V. R. B. (2023). As mídias digitais no campo educacional: um olhar pelas aplicações do chat GPT na educação. *Revista Científica Multidisciplinar*, 4(7), e473556.  
<https://doi.org/10.47820/recima21.v4i7.3556>
- Graham, F. (2023). Tools such as ChatGPT threaten transparent science; here are our ground rules for their use, *Nature*, 613, 612.  
<https://doi.org/10.1038/d41586-023-00191-1>

- Leite, B. S. (2022). Tecnologias digitais na educação: uma visão geral. In: LEITE, B. S. (Org.). *Tecnologias Digitais na Educação: da formação à aplicação*. São Paulo: Livraria da Física, p. 17-49.
- Leite, B. S. (2023). Inteligência artificial e ensino de química: uma análise propedêutica do ChatGPT na definição de conceitos químicos. *Química Nova*, 46(9), 915-923. <https://doi.org/10.21577/0100-4042.20230059>
- Melo, V. M. L. S., Melo, B. R. S. & Silvano, A. M. C. (2021). O ensino de ciências exatas e naturais na educação básica: contribuições dos objetos de aprendizagem. *REAMEC - Rede Amazônica de Educação em Ciências e Matemática*, 9(1), e21022. <https://doi.org/10.26571/reamec.v9i1.11585>
- Milaré, T. & Alves Filho, J. (2010). A Química Disciplinar em Ciências do 9º Ano. *Química Nova na Escola*, 32(1), 43-52. [https://cabecadepapel.com/sites/colecaoaiq2011/QNEsc32\\_1/09-PE-0909.pdf](https://cabecadepapel.com/sites/colecaoaiq2011/QNEsc32_1/09-PE-0909.pdf)
- MINAYO, M. C. (2009). *Pesquisa social: teoria, método e criatividade*. Rio de Janeiro, RJ: Vozes.
- Moura Júnior, M. D., Maranhães, C. M. C., Diana, J. V. A. & Oliveira, P. C. (2020). Ensino de ciências exatas para jovens em situação de vulnerabilidade social e econômica. *Revista Eletrônica de Extensão*. 17(35), 56-67. <https://doi.org/10.5007/1807-0221.2020v17n35p56>
- Oliveira, J. V. N., Vieira, S. A. G., Lopes, T. B. & Beites, P. D. (2023). Elaboração de projetos de pesquisa com auxílio do ChatGPT: um estudo com licenciandos de matemática. *Revista REAMEC*, 11(1), e23064. <https://doi.org/10.26571/reamec.v11i1.15966>
- Oliveira, J. M. S., Siqueira, R. A. & Almeida, R. (2023). Três faces do ChatGPT: imaginários de uma máquina de linguagem. *SCIAS - Educação, Comunicação e Tecnologia*, 5(2), 104–123. <https://doi.org/10.36704/sciaseducomtec.v5i2.7906>
- OpenAI. (2024). *ChatGPT-PRO 4.0*. [Large language model]. <https://chat.openai.com/chat>
- Paraná. (2021). Secretaria de Estado da Educação e do Esporte (Paraná). *Referencial curricular para o ensino médio do Paraná*. Curitiba, PR: SEED/PR.
- Parreira, A., Lehmann, L. & Oliveira, M. (2021). O desafio das tecnologias de inteligência artificial na Educação: percepção e avaliação dos professores. *Ensaio: Avaliação e Políticas Públicas em Educação*, 29(113), 975–999. <https://doi.org/10.1590/S0104-40362020002803115>
- Sant'ana, F. P., Sant'ana, I. P. & Sant'ana, C. C. (2023). Uma utilização do Chat GPT no ensino. *Uma utilização do Chat GPT no ensino*, v. 8, n. 20, p. 74–86. <https://doi.org/10.23864/cpp.v8i20.951>

- Silva, L. A. & Simões Neto, J. E. (2022). Uma sequência didática sobre o conceito de energia utilizando questões sociocientíficas a partir da Teoria dos Perfis Conceituais. *Química Nova na Escola*, 44(4), 392-400.  
<http://dx.doi.org/10.21577/0104-8899.20160334>
- Stokel-Walker, C. (2023). ChatGPT listed as author on research papers: many scientists disapprove. *Nature*. 613, 620-621. <https://doi.org/10.1038/d41586-023-00107-z>
- Tate, T. P., Doroudi, S., Ritchie, D., Xu, Y. & Warschauer, M. (2023). Educational Research and AI-Generated Writing: Confronting the Coming Tsunami. [preprint in EdArXiv]. <https://doi.org/10.35542/osf.io/4mec3>
- Teixeira, R. R. P. & Souza, D. C. P. (2022). Matéria escura, energia escura e história da ciência na educação científica. *ACTIO: Docência em Ciências*, 7(2), 1-22.  
<http://dx.doi.org/10.3895/actio.v7n2.14046>
- Zamboni, A. & Bezerra, L. M. (2020). *Ser Protagonista: Ciências da Natureza e suas tecnologias: Composição e estrutura dos corpos*. Ensino Médio. São Paulo, SP: Edições SM.
- Zittoun, T., Valsiner, J., Vedeler, D., Salgado, J., Gonçalves, M. & Ferring, D. (2011). *Melodies of Living: Developmental Science of Human Life Course*. Cambridge University Press: Cambridge.



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**Address:**

Ismael Laurindo Costa Junior

Rua Washington Luiz, n. 491Centro, Vera Cruz do Oeste, Paraná, Brasil.

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**Correspondência:**

Ismael Laurindo Costa Junior

Rua Washington Luiz, n. 491Centro, Vera Cruz do Oeste, Paraná, Brasil.

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