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Semantic Gravity and Contextualization in the Chemistry Questions of the Brazilian National High School Examination

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Abstract: In Brazil, the quality assessment of secondary education is carried out through the National High School Examination (ENEM), which has been the main form of admission to public universities since 2009. This paper presents partial data from a research aiming to evaluate the presence of contextualization in ENEM Chemistry questions through the study of Semantic Gravity (SG) in the enunciation of the questions. We understand that the contextualization of scientific knowledge is fundamental for a way of learning that enables the participation of citizens in social decision making processes. SG is related to the degree of knowledge abstraction and defined by the degree to which a meaning relates to a context. We developed an analytical tool through which we analyzed the grades of SG of the questions in the ENEM editions from 2019 and 2018, totaling 27 questions. Our instrument establishes six levels or degrees for SG ranging from a very strong SG (level 1), which addresses substances or products, concepts and properties of substances expressed in everyday language, to a very weak SG (level 6), which addresses models of theories and scientific explanations. Each question or enunciation can include different levels of SG and, in our analysis, we assume that, to be considered a contextualized question, its enunciation should include SG level 1. In total, 18 questions involved SG level 1, confirming that there is contextualization in the ENEM. However, we remarked some questions whose enunciations only involved levels 2 and 6 of SG, which addressed chemical knowledge in an abstract way, without relating it to a specific context. We attribute the presence of questions of this nature to the influence of the universities on the examination.

Keywords: contextualization; large-scale evaluation; semantic gravity

INTRODUCTION

The National High School Examination (Exame Nacional do Ensino Médio -ENEM), created in 1998 by the Brazilian Ministry of Education, is a large-scale examination of a voluntary and individual characteristic. Its initial objective was to annually evaluate the performance of high school graduating students, and the original exam was based on 21 skills and five competencies pointed out in the National Curriculum Parameters for Secondary Education and guided by the notions of contextualization and interdisciplinarity (Brazil, 1998).

As of 2009, public universities adopted the students' individual ENEM score as a selection criterion for entering Higher Education. As a result of this new objective, the exam changed to meet the requirements of universities, concerned with the knowledge base that entrants should present as necessary conditions (Andrade, 2012; Stadler & Hussein, 2017). However, the notions of contextualization and interdisciplinarity continued to be present in the evaluation matrix of this "new ENEM".

With its reformulation, the "new ENEM" has 180 questions divided into four different sections: Languages, Codes, and their Technologies; Natural Sciences and their Technologies; Mathematics and its Technologies; and a redaction. The exam started to be held in two days, with a total of 8.72 million confirmed registrations in 2014 – this being the largest number of participants in twenty-two years. In 2019, students with the highest averages competed for 235 thousand places, for the first academic semester of 2020, in 129 higher education institutions throughout

Brazil (Brazil, 2020).

Among the science questions included in the exam, some researchers found divergences as to what is proposed by the exam's matrix and what is actually evaluated, mainly because the exams in Natural Sciences and their Technologies do not usually address ethical, political, and social issues, primarily in chemistry questions (Fernandes, 2011; Pereira & Moreira, 2018; Silva, Rebelo & Canhoto, 2020). Most of these questions favor specific contents, valuing a content perspective, which differs from the reference matrix.

The theoretical and methodological texts that guide the construction of the ENEM exam describe what are the characteristics of the exam, described as "theoretical axes; conceptions on interdisciplinarity, competences and abilities; correction methodology, among other characteristics" (Fernandes, 2011, p. 57). The concept of contextualization, however, remains open for interpretation. According to Fernandes (2011), the term does not appear often in the official documents and the need to understand what these official texts say about contextualization is important, since these documents state that the questions of the exam ought to be contextualized.

In the teaching of Chemistry, the concept of contextualization, according to Wartha, Silva and Bejarano, (2013), is very much related to everyday life, especially the use of everyday situations for teaching scientific content. Pedagogically speaking, "contextualizing content in class with the students means first of all assuming that all knowledge involves a relationship between subject and object" (Wartha, Silva & Bejarano, 2013, p. 86). They add that the teachers' understanding of contextualization in the teaching of Chemistry is limited to:

> (...) applications of chemical knowledge, that is, they present concepts on contextualization as exemplification and illustrations of contexts to teach chemistry contents and that few teachers understand contextualization in the perspective of understanding social reality" (Wartha, Silva & Bejarano, 2013, p. 88).

The use of contextualization, by bringing scientific knowledge closer to a more concrete reality for the students, would bring the benefit of reducing the abstraction of this knowledge, a characteristic pointed out as unfavorable for the creation of interest in this discipline. In this work, we analyzed the contextualization in the statements of the ENEM's Chemistry questions through Semantic Gravity. We propose an analytical tool that explores the semantic dimension of knowledge, based on an instrument proposed by Santos and Mortimer (2019) for the study of Semantic Gravity, a concept derived from Legitimation Code Theory (Maton, 2014).

Semantic Gravity is related to the degree of abstraction of knowledge and is defined by the spatial relationship between a meaning and a context. The strength of Semantic Gravity presents a continuum between levels or degrees, represented by infinite gradations of their values. The closer the meaning is to a context, the greater the Semantic Gravity, the more abstract the knowledge, the more distant from a context and, therefore, the lower the Semantic Gravity.

The study of Semantic Gravity in scientific education research has chosen different objects for analysis, such as classroom discourse (Santos & Mortimer, 2019; Cranwell & Whiteside, 2020), learning assessment (Rootman Le Grange & Blackie, 2018), and curriculum documents (Lee & Wan, 2020).

This work presents partial data from a research in progress, and is guided by the following question: What are the degrees of Semantic Gravity (SG) in the statements of the Chemistry questions of the ENEM? Through this research we intend to investigate the organization of scientific knowledge in the statements of Chemistry questions, as well as their relationship with the contextualization of chemical knowledge in a large-scale evaluation exam.

METHODOLOGY

Our instrument proposes six levels or degrees for SG, ranging from a very strong SG (level 1), which addresses substances or mixtures, concepts and properties of substances expressed in everyday language, to a very weak SG (level 6), which involves models of theories and scientific explanations, as shown in Table 1.

Table 1
Semantic Gravity Levels for the chemical knowledge in ENEM statements. Adapted from Santos and Mortimer (2019)

Semantic Gravity	Level	Description	Example
strong ↓ weak	1	Substance or Product of daily use/Concepts in their daily use/1st Order Properties and Behavior	"To perform the unblocking of residential sewer pipes, a **solid commercial mixture** is used."
	2	Substance or mixture in its chemical nomenclature/Chemical reaction/2nd order properties and behavior	"(...) contains **sodium hydroxide (NaOH)** and another chemical powder."
	3	Classes of substances in their chemical nomenclature/Type of chemical reactions/3rd order properties and behavior	"Because they have a complete valence shell, high ionization energy and virtually no electronic affinity, it was considered for a long time that **noble gases** would not form chemical compounds."
	4	Models of structures, of composition, of calculations and chemical procedures/Scientific concepts/Relationships between models, concepts and properties and behaviors	"Graphene is an **allotropic form of carbon made up of a planar sheet (two-dimensional arrangement) of compacted carbon atoms** and only one atom thick."
	5	Principles and laws/Relationships between concepts	"**Element atoms combine with atoms of other elements in small integer proportions to form compounds.**"
	6	Models of theories and scientific explanations	"After Dalton's model, other **models based on other experimental data** showed, among other things, the electrical nature of matter, the composition and organization of the atom and the quantization of energy in the atomic model."

The analysis of the questions involved the selection of blocks of the statements containing propositions that declare some knowledge about one or more referents. We assigned SG levels to each unit of analysis, identifying their referent(s) according to the description in Table 01 (the referents were highlighted in bold in the examples).

RESULTS AND DISCUSSION

For this work we analyzed the questions from the last two editions of the exam in the years 2019 and 2018 and found a total of 27 Chemistry questions in the Natural Sciences and their Technologies exam (Table 02). Each question or statement included different levels of SG. To be considered a contextualized question, we assumed that its statement should necessarily include level 1 of SG.

Table 2
Number of statements analyzed

ENEM Edition	Questions
2018	14
2019	13
Total	27

In total, 18 questions involved level 1 of SG, which confirms the permanence of contextualization in the new ENEM, according to its founding matrix. However, we also observed questions whose statements only involved levels 2 to 6 of SG and addressed chemical knowledge in a more abstract way, without relating it to a specific context.

Table 3
Level of SG involving different levels of context

SG level	2018	2019	Total in the questions
SG1	9	9	18
SG2+	5	4	8

Below, we will present some statements of the Chemistry questions found in the exams of ENEM natural sciences and their technologies with their respective levels of SG.

O carro flex é uma realidade no Brasil. Estes veículos estão equipados com motor que tem a capacidade de funcionar com mais de um tipo de combustível. No entanto, as pessoas que têm esse tipo de veículo, na hora do abastecimento, têm sempre a dúvida: álcool ou gasolina? Para avaliar o consumo desses combustíveis, realizou-se um percurso com um veículo flex, consumindo 40 litros de gasolina e no percurso de volta utilizou-se etanol. Foi considerado o mesmo consumo de energia tanto no percurso de ida quanto no de volta.

O quadro resume alguns dados aproximados sobre esses combustíveis.

Combustível	Densidade (g mL^{-1})	Calor de combustão (kcal g^{-1})
Etanol	0,8	−6
Gasolina	0,7	−10

O volume de etanol combustível, em litro, consumido no percurso de volta é mais próximo de

A 27.
B 32.
C 37.
D 58.
E 67.

Figure 1. Question 92 of the 2018 edition of the ENEM (blue test)

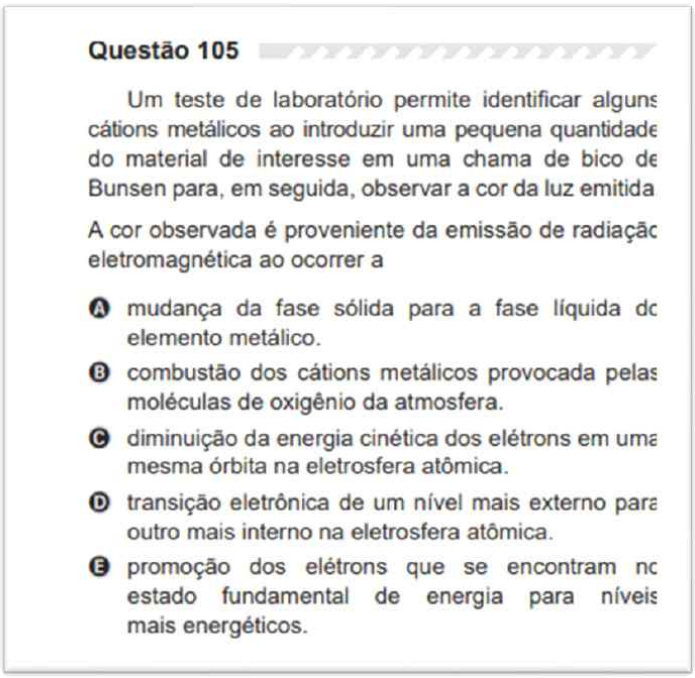
"The flex-fuel car is a reality in Brazil **(Level 1)**. These vehicles are equipped with an engine that has the ability to run on more than one type of fuel **(Level 1)**. However, people who have this type of vehicle, at the time of refueling, always have the question: alcohol or gasoline **(Level 1)**? To assess the consumption of these fuels, a route was carried out with a flex-fueled vehicle, consuming 40 liters of gasoline and on the way back, ethanol was used **(Level 2).** The same energy consumption was considered for both the outbound and the return routes.

The table summarizes some approximate data on these fuels **(Level 4)**.

The volume of the ethanol fuel, in liters, consumed on the return route is closer to **(Level 4)**.

Answer: D 58

Question 92 of the 2018 edition (Figure 1), based on the proposed analytical tool, is considered a contextualized question. It presents in its statement the level 1 of SG, when describing a "flex-fueled engine" that works with more than one type of fuel, through concepts in their daily use (we consider here alcohol and gasoline as referents in their daily use, however ethanol was considered a referent named in its scientific language). In its last block, the statement presents a change in the level of SG, to level 4, and, thus, for the candidate to answer this question they should perform a calculation based on scientific models and concepts (SG level 4).
The statement of question 105 of the 2019 edition (Figure 02) starts from the SG level 3 when taking "metallic cations" as referent and seeks to relate a property of this class of chemical substances (the color of the light emitted in a flame) to the emission of electromagnetic radiation and its application in the analytical determination based on the flame method (relationships between models, concepts, and properties), raising the SG to level 4. This question is an example of a statement that is based on a more decontextualized knowledge than the previous question and addresses the abstract knowledge of Chemistry.



Questão 105

Um teste de laboratório permite identificar alguns cátions metálicos ao introduzir uma pequena quantidade do material de interesse em uma chama de bico de Bunsen para, em seguida, observar a cor da luz emitida.

A cor observada é proveniente da emissão de radiação eletromagnética ao ocorrer a

A) mudança da fase sólida para a fase líquida do elemento metálico.
B) combustão dos cátions metálicos provocada pelas moléculas de oxigênio da atmosfera.
C) diminuição da energia cinética dos elétrons em uma mesma órbita na eletrosfera atômica.
D) transição eletrônica de um nível mais externo para outro mais interno na eletrosfera atômica.
E) promoção dos elétrons que se encontram no estado fundamental de energia para níveis mais energéticos.

Figure 2. Question 105 of the 2019 edition of the ENEM (blue test).

"A laboratory test makes it possible to identify some metallic cations **(Level 3)** by introducing a small amount of the material of interest into a Bunsen burner to then observe the color of the emitted light. **(Level 4)**

The observed color comes from the emission of electromagnetic radiation when it occurs at

Answer: D) electronic transition from a more external level to a more internal level in the atomic electron configuration.

A trend that we noticed in the exams of 2018 and 2019, through our analysis, even in the questions that have a stronger SG (between the levels 1 and 2), is a decrease in the level of semantic gravity between the body of the statement and the final question; the question that, for the most part, requires from the student knowledge that would relate chemical concepts, models, and properties (SG 4), as seen in the question in Figure 02.

CONCLUSIONS

The transformation of the ENEM into an instrument for the selection of admission to the main Brazilian universities has enormously popularized this exam in the country, strengthening its inductive role on the pedagogical practices in high schools. Being an exam of national scope and reaching a significant portion of the population that wants to enter higher education, it becomes relevant to understand how this exam configures and presents scientific knowledge in the statements of its questions. This work investigated, although partially, in the statements of Chemistry questions, the contextualization of knowledge through the analysis of Semantic Gravity and its variation in each question.

The results showed us that, based on the proposed analytical instrument, 18 of the 27 analyzed questions were considered contextualized questions. These are questions that relate chemical knowledge to some substance, mixture or property that assumes a concrete existence for us, and for which we use natural or common language. The questions that presented a weaker level of Semantic Gravity (less contextualized) demanded a domain of scientific knowledge on models, concepts, and properties, and referred to classes of substances through the use of the scientific language. The presence of questions of this nature is due to the influence of universities on the exam, and the "New Enem" prioritizing a greater mastery of students with specific curricular content, even when the statements have some level of context. Our research continues with the analysis of other editions of the exam, and with the improvement of our analysis tool.

The instrument proposed for the analysis of semantic gravity, in addition to evaluating the questions of the ENEM, can also be used in the analysis of other types of written texts, such as textbooks and student's writings. Finally, we suggest that by making the study on the textual organization of knowledge possible, semantic gravity collaborates with the studies on science teaching and learning.

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To FAPESB

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