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WAYS OF THINKING THE CONCEPTS OF ENTROPY AND SPONTANEITY USING PROBLEM-SITUATIONS

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ABSTRACT

This work is an excerpt from a research at master's level, and aims to analyze the ways of thinking about the concepts of entropy and spontaneity that emerge in the responses of undergraduate students to three problemsituations, part of a didactic sequence for discussing these concepts, from the perspective of the Theory of Conceptual Profiles. These problem-situations were developed considering contexts in which different areas of the conceptual profile have pragmatic value. The analysis of responses was carried out according to Lemke's thematic patterns, which establish semantic relations according to discursive interactions. The results point to the emergence of two zones of the conceptual profile of entropy and spontaneity, perceptual/intuitive and empirical, however, it was not always possible to identify a way of thinking about these concepts, as students avoided using the concept of entropy, seeking to use other concepts studied in school.

KEYWORDS: Conceptual Profile, Entropy and Spontaneity, Problem-Situations.

MODOS DE PENSAR OS CONCEITOS DE ENTROPIA E ESPONTANEIDADE UTILIZANDO SITUAÇÕES-PROBLEMA

RESUMO

Este trabalho é um recorte de uma pesquisa em nível mestrado, e tem por objetivo analisar os modos de pensar sobre os conceitos de entropia e espontaneidade que emergem nas respostas de estudantes de licenciatura a três situações-problema, integrantes de uma sequência didática para discussão desses conceitos, na perspectiva da Teoria dos Perfis Conceituais. Essas situações-problema foram elaboradas considerando contextos em que diferentes zonas do perfil conceitual possuem valor pragmático. A análise das respostas foi realizada de acordo com os padrões temáticos de Lemke, que estabelece relações semânticas de acordo com as interações discursivas. Os resultados apontam a emergência de duas zonas do perfil conceitual de entropia e espontaneidade, perceptiva/intuitiva e empírica, no entanto, nem sempre foi possível identificar um modo de pensar sobre esses conceitos, pois os estudantes evitaram utilizar o conceito de entropia, buscando utilizar outros conceitos estudados no Ensino Médio.

PALAVRAS CHAVE: Perfil Conceitual, Entropia e Espontaneidade, Situações-Problema.

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1 INITIATING THE DEBATE: TEACHING AND LEARNING THE CONCEPT OF ENTROPY

School-level Science class approach on the concept of entropy, quite important in the studies on thermodynamics and chemical thermodynamics, focus on the definition and use of the change in entropy, **dS**, which occurs as a result of a physical or chemical process, motivated by the idea that such variation leads to a dispersion of the energy, which depends on the amount of energy that is transferred as heat, based on the idea that it is the heat that stimulates random movements (Atkins and Paula, 2010). Thus, we assume that if the heat is transferred to the system, an increase in energy dispersion should occur. Since entropy should be a state function, and the heat differential is an inexact differential, the temperature inversion appears as a simpler integration factor, which makes entropy a state function, In other words, it depends only on the initial and final states, and not on the trajectory, as we show on Equation 1, in which $\mathbf{dq_{rev}}$ is the heat associated to a reversible process and T is the temperature in which this process evolves.

$$dS = \frac{dq_{rev}}{T}, \qquad \text{Equação 1}$$

By the definition shownn, we notice that the concept of entropy is not simple and demands, for its full understanding, and adequate knowledge of thermodynamics, as well as a powerful abstraction capacity and comprehension of the mathematics involved in its formulation. The difficulty to understand this concept has already been discussed in several works in the field of Science teaching (Colovan & Silva, 2005; Almeida, 2011; Cunha, Santos & Queiroz, 2013; Guimarães, Silva & Simões Neto, 2019) and may be related to the superficial, or many times non-existant, approach in the classrooms in High School. For this work, we will highlight the discussion over the concept on-screen following the pathway trodden by Amaral (2004), in a doctorate level work that discussed the concepts of entropy and spontaneity and the 2nd law of Thermodynamics considering the Theory of Conceptual Profiles (Mortimer, 2000; Mortimer & E-Hani, 2014).

Such theory emerged in Brazil in the context of Science teaching, initially as a notion that aimed to organize the heterogeneity of ways of thinking certain scientific concepts in the classroom, later becoming a learning theory of South-American origin. In it, we consider that people show different ways of seeing and conceptualizing the world, and thus, show different ways of thinking, used in an efficient way in different scenarios. For a conceptual profile of a certain concept, we establish zones, which represent these different ways of thinking about the concept, and that hold pragmatic value in specific contexts, which may coexist in an individual, translating a plurality of epistemological, ontological and axiological commitments. It is this pragmatic value that determines the relationship between a way of thinking and the most appropriate context of utilization (Mortimer et al., 2014).

We can think of the Conceptual Profiles Theory for the organization of didactic proposals for the classroom (Simões Neto et al., 2015; Amaral, Silva & Sabino, 2018). For Ribeiro (2013), thinking about the didactic activities based on the theory in question allows us to follow the evolution of the ideas of the individuals over a certain concept, to observe the relationship between the constitution of the different zones of a conceptual profile and the influence of the context, to enable not only the increase of known and established ways of thinking, but also the awareness of the diversity of meanings that one concept may accept, and their implications on the teaching and learning processes, with such processes being related in what is called dimension of learning. It is in this direction of work, growing in the research program on Conceptual Profiles, that the present work is situated.

Amaral and Mortimer (2004) showed a proposal of Conceptual Profile for entropy and spontaneity, considering the methodology of usual proposition (Mortimer & El-Hani, 2014), from ideas of the history of Science, literature in teaching of Sciences, mostly about informal or alternative conceptions, and from data obtained from the classrooms. Initially, four zones were proposed, but after the profile was revisited, these were reorganized in three (Amaral, Mortimer & Scott, 2014), shown in Table 1.

1: Conceptual Profile of Entropy and Spontaneity

Zone	Definition
Perceptive/Intuitive	Relates to the ideas of spontaneity that emerge from the immediate impressions, from the sensations and intuitions, and that don't consider the conditions in which the processes occur, that is, the idea of understanding a phenomenon as spontaneous, not caring about its causes.
Empirical	This is related to the ideas in which the experience starts to be analyzed, considering the conditions in which the processes occur.
Rationalist	Understands the mathematical formalism and the ideas about the spontaneity of the processes that consider the distribution of energy in an atomic-molecular level.

Considering what was exposed in our initial debate, the present article aims to analyze the ways of thinking about the concepts of entropy and spontaneity that emerge in the answers from undergraduate Chemistry students given to three problem-situations, which compose a didactic sequence for the discussions of these concepts, seeking a look towards learning in the perspective of the Three Conceptual Profiles.

2 THE DIDACTIC STRATEGY USED: PROBLEM-SITUATIONS

Teaching Science from problem-solving is, in Science Didactics, a clear way to establish a more active attitude in the student on classroom, which seems essential to us in order to develop the autonomy, responsibility, potential for collaboration, and above all, intrinsic motivation, in other words, to make that learning Science happens from a place of will to learn, not just to obtain good grades or to justify the parents' and/or the whole school community's investment (Silva & Simões Neto, 2018).

Thus, to approach the concepts of entropy and spontaneity in the classroom, we considered the idea of problem-situations, proposed by Meirieu (1998). For the author:

> A didactic situation in which the subject is proposed a task that they cannot complete without realizing a precise learning. And this learning, which

> constitutes the true goal of the problem-situation, is done when one overcomes obstacles in the execution of the task (p. 189).

In general terms, a problem-situation is a didactic strategy in which a situation is established, with a defined context, and an obstacle, which must be overcome in a moviment that configures learning, in the sense that only if the obstacle is indeed overcome, learning will be effective.

Beyond the two essential elements already cited, a problem-situation must contain two other devices necessarily installed in its structure. The first, that must give conditions for the accomplishment of the task the overcoming of the obstacle, may be structured in support texts, multimedia, dialogue spaces, among others, with the goal of allowing the necessary learning for overcoming the obstacle. The other, called restriction system, is a direction with the goal of avoiding the consideration of banal answers, in other words, it informs that the necessary answer for overcoming the obstacle must be structured and must meet the criteria outlined at the start of the activity.

The problem-situations were elaborated considering as contexts situations in which a specific way of thinking, associated to one of the three zones of the conceptual profile of entropy and spontaneity, has considerable pragmatic value. In other words, use, as context, situations in which the ways of thinking related to the perceptive/intuitive, empirical and rationalist zones (Mortimer, 2001) emerge in the ways of speaking.

Thus, the elaborated problem-situations are shown next, on Table 2.

Table 2: Problem-situations

Order	Problem-situations
1	An exposition on science and art was being organized by the scientific dissemination group of a University on Pernambuco's *agreste* region. One of the works exposed was the Sidney Harris cartoon shown next. Based on the image and on your knowledge of thermodynamics, what is the main idea on entropy shown in the cartoon? Which elements of the image corroborate your identification of this idea?  **Figure 1: Cartoon "Dept. of Entropy", by Harris**

2	The human being has the power to change the world! Since prehistory until the present days, the planet has been subjected to many modifications, with today the landscape being totally modified by the advancements of science, technology, engineering and architecture. Observe the sequence of images and answer: how the concepts of entropy and spontaneity may help explain these phenomena?  **Figure 2: Sequence of images "the human being modifies the world"**
3	When we fuel a car, we are thinking of the energy that this fuel may provide to put it in movement. Based on the laws of thermodynamics, we know that the energy is conserved in all of the physical, chemical and biological processes. However, we cannot ride the car without fueling it again after a few days. If energy is conserved, why do we have to regularly fuel the automobiles with more fuel? Provide two explanations for the question, considering macroscopic and microscopic aspects.

Although each question has been elaborated focusing in a specific way of thinking, all of the conceptual profile zones may emerge in each of the problem-situations (Simões Neto et al., 2015). In the effective work in the classroom, we organized a printed material containing the three problems, which were made available to the 18 students that participated in the research, who were divided in two groups. The time allotted to the conclusion of the task was 50 minutes, and after the time was up, each group presented, in no more than five minutes, their answers to their colleagues, with the classroom organized in a circle. At the end of the class, the answers to the problem-situations were given, these being the data obtained for the clipping shown in this text.

3 THEMATIC PATTERNS

The answers given by both groups for each of the problem-situations were analyzed using the thematic patterns from Lemke (1997), considering the idea that learning Science is associated to learning the language of Science, including aspects related to reading, writing, interpreting and solving problems by use of this specific language. In order to understand the relationship between the meaning of the words, the author proposes the use of a tool called thematic diagram, which is a way to represent the thematic pattern produced in the discursive interactions in the classroom, or in any other discourse about Science.

The way one speaks about a subject matter may differentiate them or include them in a social group. Insofar as the individuals participate in a community, the things that they say are not different than what other members say, with the tendency that they arrive to the same meanings pattern. However, there may be differences in the patterns, due to specific questions such as theories, opinions, values systems, which may be different for a determined portion of members of a group.

We can understand the thematic pattern as a way that a community speaks on a subject, being made up by thematic items, elements that may be said in different ways, for example sound, soundwaves, vibrations, but they all express the same idea. The different thematic items hold a relationship between themselves, called semantic relationship.

Our proposal for using the thematic patterns is based on the work of Silva (2017), structured in four steps: (1) identifying excerpts in which the concepts of entropy and spontaneity are expressed in the answers; (2) building/identifying the thematic items, science terms and terms related to common sense; (3) building the semantic relationships established between each term; (4) joining these semantic relationships in a thematic pattern.

We opted for not building a thematic diagram, since, in our vision, it's more interesting to perceive the emergence of the zones of the conceptual profile of entropy and spontaneity, to work with organization tables for the thematic items and the semantic relationships. In order to facilitate the identification of the thematic items, we aim, in the presentation of the results, to highlight the excerpts that are related to the investigated domain, using charts. All names used for the participants on the research are fictional, to ensure the ethical questions of the research involving human beings.

At last, we highlight that the semantic relationships describe how these thematic items relate to each other, i.e., what two words or phrases mean, when used together to speak about the theme in question. Here, we will use some semantic relationships based on Lemke's proposal: nominal relations, transitivity relations, identification/possession relations, circumstantial relations and relations that occur between whole sets of linked items.

4 WAYS OF THINKING THE CONCEPT OF ENTROPY AND SPONTANEITY

In the proposed analysis, we aimed to map the ways of thinking, from the identification of the different ways of speaking (Mortimer,2001) made explicit in the students' answers form the problem-situations. Thus, we accessed the ways of thinking from observing the emergence of the ways of thinking the concepts of entropy and spontaneity, in the answers of the Chemistry undergraduate students and, with that starting point, we characterized three profile zones, showing the plurality of meanings of the concept of entropy and spontaneity when put in use in day-to-day situations.

Initially, we will highlight the answers for the first problem-situations, which focuses on the perceptive/intuitive zone, to then discuss the second problem-situation, associted to the empirical zone, and, at last, we will discuss the third problem-situation, related to the rationalist zone.

4.1 Problem-Situation 1 (PS1)

On Chart 1, we show the answers presented by the two groups on the resolution of the first problem-situations, transcribed exactly as they were presented, such as speech turns referent to the discussions performed in the classroom.

Chart 1: Answers and discussion -PS1

Identification	Answers

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Group 1	Answer	From the image, it is possible to deduce that the conceptual model of entropy is related to the disorder of the system. Macroscopically, we have that the system is the room, and the disorganization of the envornment is related to the scattered files, the broken wood floor, the scattered trash etc.
	Discussion	Helena: *"I mean, we can observe that his research field, which is* ***entropy, has taken over all that is around him, and we can see that the whole room is in true chaos, true disorder****, then that's what we could relate to the term entropy, that this is the entropy department, i.e., his research field with all of the room, from the door to the papers, everything."* *Researcher: "And what about spontaneity, is it spontaneous, non-spontaneous?"* Helena: *"These things that happened we can say that* ***it was a spontaneous process****, that, I don't know about the door, but the crack in the wall, it might have happened with time, it's something that fell off, the papers that went out of order, that wasn't him who did it, out of nowhere,* ***it happens with time****, in a* ***spontaneous process."***
Grupo 2 Group 2	*Answer*	The disorder of the system (room), the floor, wall, the glass, the door, trash, archive, clock, table. It is spontaneous, because it is noticeable that some objects are affected by time.
	Discussão Discussion	Rafael: *"But in fact we can observe that there are processes that also contributed, like the knocked down trashcan, the phone out of the hook, the door might have been a process that influenced, but in fact, even then he had to open it in order to enter the room."* Mariana: *"It also shows that the disorder affected so much that it wasn't just the room, it affected himself, in the tie with the loose knot, the shirt buttons and even his shoelace is untied."* Mediator: *So you are confirming that the disorder occurs in the whole system, and not only on certain places. Including on the person himself, there is disorganization, which is why the whole environment is contemplated. Somebody else? In this sense, we also have what is characteistic of the entropy, this disorder, so that is represented on the cartoon through the* ***disorganization of the place*** *and the person as a reflection of the whole system.*

From the interactions related to the resolution and presentation of the answers for the problem-situation 1, we identified the thematic items and the semantic relations of each group, which are shown on Chart 2.

Chart 2: Systematization of the semantic relations present in the answer of PS1

Groups	Thematic item	Semantic Relation*	Thematic item
Group 1	Entropy	Agent/process	Disorder of the system

	Entropy	Agent/process	System (room)
	Entropy	Carrier/attribute	Disorganization of the environment
	Entropy	Classifier/thing	Scattered files
Group 2	Entropy	Part/whole	Disorder of the system
	Entropy	Agent/process	System (room)
	Entropy	Thing/Classifier	Spontaneous process
	Entropy	Carrier/attribute	Objects affected by time
The denominations before the slash (/) consist on the role played by the preceding term, followed by the role played by the nex term in the semantic relation.			

From the analysis of the answers, it was possible to identify the thematic items entropy, disorder (of the system), disorganization, system (room), spontaneous process. We notice the emergence of ways of thinking associated to two zones, as seen on Chart 3.

Chart 3: Conceptual profile zones for entropy and spontaneity for the answers of PS1

Group	Answer	Zone
1	From the image, it is possible to deduce that the conceptual model of **entropy** is related to the **disorder of the system**. Macroscopically, we have that the **system** is the **room**, and the **disorganization** of the environment is related to the scattered files, broken wood floor, scattered trash etc.	Empirical
2	The **disorder** of the system (room); the floor, the wall, the glass, the door, trash, archive, clock, table; **spontaneous**, since it is noticeable that some objects are affected by time	Perceptive/Intuitive

Considering the thematic items identified in answers of the two groups of sudents, we notice that they can establish a relation that the room presented in the cartoon, representing a fictional department of entropy, is disorganized, i.e., everything is out of place, in reference to the objects that are damaged or placed in seemingly inadequate places. Such disorganization is identified as a spontaneous action, which happened during a certain time.

It was possible to identify through the words highlighted in bold the emergence of the empirical zone on the way of speaking in the answer presented by group 1, which relates entropy to the disorder of the system, with the system being the room and the disorganization observed from the structural damages and trash hoarding, for example, based on the idea that the measurement of a degree of disorder is intimately linked to entropy: disorganized room indicates high entropy. Group 2 presented an answer that we relate to the ideas of the perceptive/intuitive zone, by the highlight given to the idea of spontaneity, relating the lack of organization and deterioration of the space to a spontaneous process going in direction of maximum entropy, holding a direct relation between the two concepts.

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4.2 Problem-Situation 2 (PS2)

On Chart 4, there are the answers presented for the second question, as they were delivered, and also the exact transcription of the discussions that occurred in the classroom, when the answers were presented.

Chart 4: Answers and discussion – PS2

Identification		**Answers**
Group 1	Answer	Initially we have a natural landscape, then a mineral deposit where the entropy of the universe tends to increase, following the images we have the extraction of the mineral, the raw material, and in the end the final poduct, this way it occurs the influence of an external agent (the man) performing work on the environment, making it that there is an organization of the environment, therefore is an irreversible non-spontaneous process.
	Discussion	Pedro: *"As it was already said initially, we have the natural landscape, which is a mineral deposit, then the extraction of the raw material occurs, and then it is manufactured, and the final product of all of this is the Eiffel tower. In other words, the concepts of entropy are related to the natural landscape, that we have then a higher entropy than in the final product, because a non-spontaneous transformation occurs, since it has the intervention of an external agent, which in this case is the man. So, the entropy* ***through these images decreases because an organization occurs****, since initially we have the total disorganization of the natural landscape of the universe. And at last, we have a series of stages in which the organization of all this raw matrial generated a final product."* Helena*: "That the man was the main responsible in order to make, from the deposit, until we get to the Eiffel tower. So, we see it as a non-spontaneous process.*
➢ Group 2	Answer	Through time, the entropy decreases because of the action of the man, so it is not spontaneous, since the transformation is retained. The transformation is physical, but the oxidation of the metal is chemical.
	Discussion	Rafael: *"We can observe that it is* ***a physical transformation of the matter****. Therefore… (inaudible). Also, in fact looking at the images individually, the first being the deposit and the third, the iron,* ***is a spontaneous process****…"*

From the transition of the discussion related to the problem-situation 2, the thematic items and semantic relations of each group were identified: entropy of the universe tends to increase, influence of an external agent (the man), performing work, organization of the environment, irreversible non-spontaneous process, action of the man, non-spontaneous process and transformation, as we show in the systematization organized next in Chart 5:

Chart 5: systematization of the semantic relations present in the answer for PS2

Groups	Thematic item	Semantic relation*	Thematic item
Group 1	Mineral deposit	Carrier/attribute	Entropy of the universe
	Mineral deposit	Thing/classifier	Increase (extraction, raw material, product)
	External agent (man)	Carrier/attribute	Achievement (work)
	Organization of the environment	Agent/process	Reversible non-spontaneous process
	Entropy	Agent/process	Decreases (action of man)
Group 2	Entropy	Agent/process	Non-spontaneous process
	Non-spontaneous process	Thing/classifier	Transofrmation withdraws
	Transformation withdraws	Thing/classifier	Physical transformation
	Physical transformation	Agent/process	Chemical transformation (oxidation of the metal)
*The denominations before the slash (/) consist on the role played by the preceding term, followed by the role played by the nex term in the semantic relation.			

Working on the second problem-situation, we noticed the emergence of two conceptual profile zones of entropy and spontaneity, with a highlight for the occurrence of a hybrid speech, that relates more than one zone of a determined conceptual profile in the same speech. The zones that emerged are shown on Chart 6.

Chart 6: Conceptual profile zones for entropy and spontaneity for the answers of PS2

Group	Answer	Zone
1	Initially, we have the natural landscape, a mineral deposit in which the **entropy of the universe tends to increase**, in the following images we have the extraction of the metal, the raw material, and at last the product, thus it occurs the **influence of an external agent (the man) performing work** on the environment, making it so that there is an **organization of the environment** and, therefore, it is a **irreversible non-spontaneous process**.	Empirical Perceptive/Intuitive
2	Through time, **the entropy decreases** due to the **action of man**, so it is **non-spontaneous**, since the transformation is withdrawn. The **transformation** is physical, but the oxidation of the metal is chemical.	Empirical Perceptive/Intuitive

The existent relation, by the identification of these thematic items, occurs due to the organization of the processes, promote by hyman action, since women and men can change the world and organize the system through transformation. Therefore, the process, since the extraction of the raw material until the final product, is non-spontaneous, since it does not occur naturally and people perform the work responsible for all of the process.

From the thematical items identified, it was possible to verify the emergency of the perceptive/intuitive and empirical zones of the conceptual profile, in the answers elaborated by both groups. We highlight that, in the answers of the two groups, we notice the existence of hybridism, i.e., the emergence of more than one way of thinking about the concepts of entropy and spontaneity in the same statement (Diniz Jr., Silva & Amaral, 2015), being possible to identify the empirical zone in affirmations related to measuring greatness, like in "*entropy of the universe tends to increase*" (group 1) and "*the entropy decreases*" (group 2), and the perceptive/intuitive zone, when highlighting the action of the human being as an external agent in order to perform the work of transformation ot the environment, making a non-spontaneous process occur.

4.3 Problem-Situation 3 (PS3)

On Chart 7, we present the two answers for the resolution of the third problem-situation, transcribed exactly as they were presented by the groups, and also the discussions performed in the classroom.

Chart 7: Answers and discussions – PS3

Identification		Answers
Group 1	Answer	It is necessary to fuel the vehicle, since the primary source of energy (fuel) was consumed, making it impossible to perform work. This way, since there is conservation of energy, the performing of work makes it possible to convert the primary energy of the fuel is converted in kinetic energy, through the processes of exhaustion, combustion etc.
	Discussion	Helena: "We can also compare that it is not a perfect machine, so it can't continue to work that cicle, i.e., if it were a perfect machine, we would put gasoline once and then it would be in a cycle introducing 100%. But, as we can see, **the car releases, let's say, by the exhaust pipe that a certain amount is released, the other amount is dissipated in form of heat in the motor and also various ways that we can say that we lose this type of energy, be it for the environment or for the internal functioning** etc." Lúcio: "It's because inside the car, it occurs the transformation of the **thermal energy to kinetic energy**, which in case is the burning of the fuel that makes that the kinetic energy is created and the car starts to move"

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Group 2	➢ Answer	The energy is conserved only if the motor is on. Macro: the energy is transformed to work, which is irreversible during the spending of the fuel; Micro: the combustion reaction in the system. Which occurs in the burning of the fuel, where the molecules are excited and consumed.
	Discussion	Cecília: *"The **transformation is microscopical** is also justified when speaking about the **burning of the fuel**, where the **molecules that make up the fuel itself, they are excited**, and in this case are consumed precisely in order to the work occur."* Rafael*: "**The macroscopical part** could in fact be everything since the beginning when you put the fuel, that we observe by the parts of the clock that we think it is being consumed, i.e., it's the **macroscopic part** of basic facts. And the **microscopic** would be the burning, which is the utilization of the **fuel** not being 100% sufficiente, because when releasing CO_2, and the CO_2 is the energy source that even then we release through the car's exhaustion, so that's this energy."*

From the analysis of the answers elaborated for the problem-situation 3, it was possible to identify the thematic items and the semantic relations established by each group: Energy, energy conservation, fuel, kinetic energy, macroscopic, microscopic, system combustion, molecules, work. However, the idea of energy degradation, which is related to situations in which a determined form of energy transforms itself in other, that is not useful anymore to the process of interest, as not used by any of the groups, when proposing the resolution of the problem-situation 3. The systematization of the analysis shown next, on Chart 8.

SP3 Chart 8: Systematization of the semantic relations present in the answer of PS3

Groups	Thematic item	Semantic relation*	Thematic item
Group 1	Primary energy source (fuel)	Whole/part	Consumption
	Consumption	Agent/process	Impossibility to perform work
	Impossibility to perform work	Agent/process	Conversion of primary energy
	Conversion of primary energy	Agent/process	Kinetic energy
	Kinetic energy	Agent/process	Exhaustion and combustion process
Group 2	Conservation of the energy	Agent/process	Macroscopic
	Macroscopic	Thing/classifier	Energy transformed in work

	Energy transformed in work	Agent/process	Irreversible process
	Irreversible process	Carrier/attribute	Fuel expense
	Fuel expense	Agent/process	Microscopic
	Microscopic	Agent/process	Combustion reaction in the system
	Combustion reaction in the system	Part/whole	Fuel burning
	Fuel burning	Agent/process	Molecules excited and consumed
*The denominations before the slash (/) consist on the role played by the preceding term, followed by the role played by the nex term in the semantic relation.			

For group 1, the relations identified demonstrate the idea that it is necessary to refuel the car eventually, because the fuel is a primary energy source, necessary for the adequate funcioning of the automobile, i.e., without it, the car would not be capable to move. For group 2, the energy is only conserved if the motor is on, showing an inexistent condition for the process.

We notice that none of the answers uses the concepts of entropy and spontaneity, thus we infer that there was no emergence of any zone of the conceptual profile in the answers to this problem-situation. Thus, we highlight the centrality of the discussion about the process of energy conservation, as said before, without highlighting the degradation of energy, a process more associated to the concept of entropy.

However, in the discussion held after the presentation of the answer of the first group, we pointed to the snippet where the participant Helena affirms that the car is not a perfect machine, and, consequently, “can’t continue making that cycle”, and that only if it were perfect, “we would put gas only once and it would stay in a cycle introducing 100%”. The participant also uses the idea that a certain amount of energy is **dissipated** in the form of heat by the motor, into the environment. We can perceive indication of utilization of scientific language, in the use of concepts such as heat and entropy, and in terms such as dissipated energy, for example. Such evidence allows us to infer that there is an emergence of the rationalist zone of the conceptual profile of entropy and spontaneity, however, in the discussion, not in the answer to the problem-situation.

5 SOME CONSIDERATIONS

For this work, which is a part of a more ample research about teaching and learning the concepts of entropy and spontaneity from the conceptual profile, we aimed to discuss the potential of three problem-situations, integral parts of a didactic sequence, in making emerge different ways of thinking, in ways of speaking, about such concepts, by showing as contexts situations in which the different meanings shown hold considered pragmatic value, making it possible to map the zones of the conceptual profile of entropy and spontaneity (Amaral & Mortimer, 2004). The analysis of the answers to the problem-situations was performed using the proposal of Silva (2017), which in turn is anchored in the thematic patterns of Lemke (1997), which establish semantic relations according to discursive interactions, in addition to the identification of the zones of the conceptual profile of entropy and spontaneity.

Our results point to the predominant emergence of two zones, the perceptive/intuitive zone, in a higher number of occurrences, and the empirical zone. We did not recognize any situation where the rationalist zone emerged, except for the contribution of a single participant at the moment of the discussion about the third problem-situation, but in an one-off and isolated way. A possible reason for the absence of this way of thinking in the answers may be in evident option of the students that participated in the research, who avoided, mainly in the moments of speaking and debating, to approach the concept of entropy, looking to discuss making use of other, more familiar thermodynamics concepts, that were studied with more attention since High School.

At last, we highlight the emergence of two zones of the conceptual profile in the same statement, which characterizes the presence of a hybrid discourse, i.e., different ways of thinking that emerge in the same answer.

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