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The fish out of water: an investigative proposal for teaching substances and mixtures in the second cycle of elementary school

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ABSTRACT

In elementary school, chemistry is associated with science teaching and, in general, it is only in the last year of this school stage that chemical concepts and language are introduced. In this context, the goals regarding the development of teaching and learning processes are not considered to be simple and linear, and there is a need to implement coherent and innovative teaching plans. Among the possibilities for developing innovative proposals is the Multistrategic Didactic Unit (MDU). This planning model comprises a teaching project that integrates a set of teaching strategies, organized according to previously defined learning goals and guided by a given methodological approach. The process of implementing a MDU entitled "Water Pollution" for teaching substances and mixtures through the Inquiry-Based Teaching approach and its impacts on the learning of 9th grade elementary school students is discussed. To this end, during the development of an action research project, audio and video recordings were made, the research teacher produced reflection journals and the students' activities were collected, the transcription of which was analyzed using Content Analysis procedures. The findings, based on the investigative approach, demonstrated positive impacts on the students' learning of the main chemical concepts, as well as promoting educational situations of autonomy and collaborative work.

KEYWORDS: Unity Plan; Science teaching; Action Research; Teaching-Learning Activities; Pedagogical Experience.

O peixe fora d'água: uma proposta investigativa para o ensino de substâncias e misturas no segundo ciclo do fundamental

RESUMO

No Ensino Fundamental, a Química está associada ao ensino de Ciências e, em geral, é somente no último ano dessa etapa escolar que os conceitos e a linguagem química são inseridos. Nesse contexto, as pretensões relativas ao desenvolvimento dos processos de ensino e aprendizagem não são consideradas como de execução simples e lineares, havendo a necessidade de implementação de planejamentos didáticos coerentes e inovadores. Dentre as possibilidades para o desenvolvimento de propostas inovadoras, encontra-se a Unidade Didática Multiestratégica (UDM). Tal modelo de planejamento compreende um projeto de ensino que integra um conjunto de estratégias didáticas, organizadas de acordo com objetivos de aprendizagem definidos previamente e orientados em função de uma dada abordagem metodológica. Discute-se o processo de implementação de uma UDM intitulada "Poluição da água" para o ensino de substâncias e misturas por meio da abordagem de Ensino por Investigação e seus impactos na aprendizagem de alunos do 9° ano do Ensino Fundamental. Para tanto, durante o desenvolvimento de uma pesquisa-ação foram realizadas gravações de áudio e vídeo, produção de diários da professora pesquisadora e coleta das atividades dos estudantes, cuja transcrição foi analisada por meio dos procedimentos da Análise de Conteúdo. Os resultados obtidos, pautados na abordagem investigativa, demonstraram impactos positivos na aprendizagem dos principais conceitos químicos pelos alunos, bem como promoveram situações educacionais de autonomia e trabalho colaborativo.

PALAVRAS-CHAVE: Planejamento Didático-Pedagógico; Ensino de Ciências; Pesquisa-Ação; Atividades de Ensino-Aprendizagem; Experiência Pedagógica.

INTRODUCTION

According to Sanmartí (2002), the acquisition of scientific knowledge cannot be considered a simple and linear process based on punctual didactic actions, such as oral presentations followed by classroom activities. For the author, students' common-sense ideas and their alternative conceptions strongly influence the process of learning Science.

In the Brazilian basic educational context, Chemistry teaching is influenced by different national curriculum guidelines, established and modified over the years. However, as Zanon and Palharini (1995) point out, within the scope of Natural Sciences for basic education, in the elementary school stage, textbooks exert a decisive influence on the content to be taught by teachers for the Chemistry curriculum component. Milaré and Alves Filho (2010) emphasize that in the last year of Middle School, despite the possible curriculum updates, most textbooks present units exclusively focused on the content of Chemistry and Physics components.

Furthermore, with some exceptions, the teaching practices used during Middle School years for teaching these curricular components are predominantly based on a teaching proposal that Freire (2015) called a "banking conception of education." This conception states that teachers guide students through a teaching proposal based on the mechanical memorization of content and there is a metaphorical conception that learners are like containers to be filled with disconnected disciplinary content.

Given these considerations, Silva and collaborators (2023) highlight the importance of: i) using innovative didactic strategies and methodological approaches for Science teaching, more precisely regarding Chemistry teaching in Middle School years; ii) determining and considering alternative conceptions related to the scientific content addressed in the school series in question; iii) implementing teaching and learning projects capable of encompassing innovative didactic strategies, based on investigative approaches.

Moreover, the National Common Curricular Base (BNCC) advocates, for the final years of Middle School, the need "to explore the students' experiences, knowledge, interests, and curiosity about the natural and material world" (Brazil, 2017).

From this perspective, the development of chemical language and its concepts is crucial. Nevertheless, reality shows that these considerations are not adequately explored in teachers' planning and didactic actions. The consequences of this scenario result in detrimental effects on the contextualization of conceptual content, as well as the composition of procedural and attitudinal content (Zanon & Palharini, 1995; Silva, Barbosa & Amaral, 2000; Alves & Gomes, 2021).

Thus, this paper aims to investigate the impacts of implementing a didactic-pedagogical plan, based on innovative and investigative perspectives, on the teaching and learning process of substances and mixtures involving Middle School students.

THEORETICAL FRAMEWORK

This work involved conducting an action research project where there was a cyclical and investigative movement of planning a Multistrategic Didactic Unit (MDU) for teaching Substances and Mixtures in a Middle School, its implementation in a regular classroom and the replanning of the MDU based on the results and reflections produced.

The MDU was planned according to the foundations of Inquiry-Based Teaching (Carvalho, 2013) and explored the use of two case studies (Sá, Francisco & Queiróz, 2007) for teaching substances and mixtures.

The reason for choosing these curricular contents is related to the fact that they constitute an introductory and determining topic for understanding various other concepts in the field of Chemistry teaching. However, it is observed that students have difficulties learning these concepts due to factors such as the lack of adequate textbook approach; the inherent complexity of establishing possible connections with other content; the absence of relationships between the atomic and macroscopic levels; and the influences of students' alternative conceptions on the learning process (Araújo, Silva & Tunes, 1995; Milaré & Alves Filho, 2010).

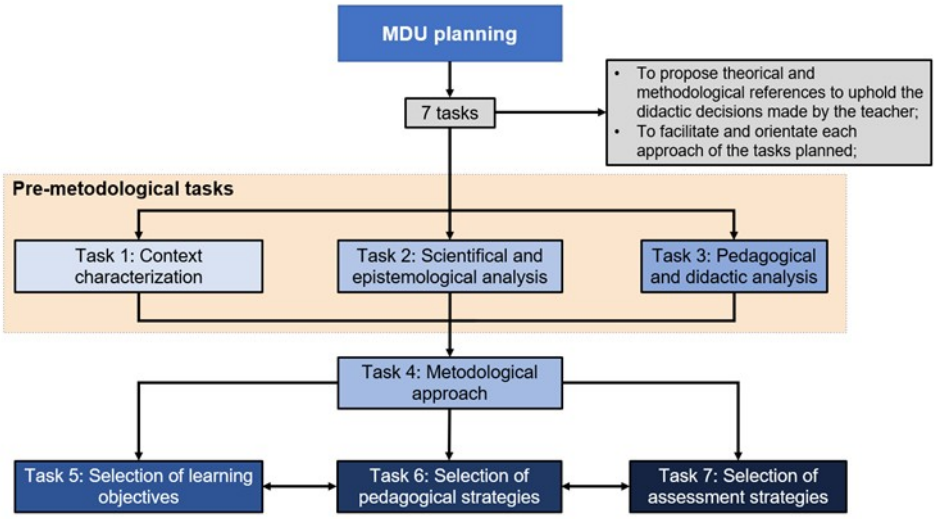
Regarding teacher planning, several studies have pointed out to the prevalence of proposals that are detached from their context of application; the mistaken notion that experiential knowledge does not interfere with the design of planning; the idea that students' alternative conceptions do not interfere with decision-making regarding planning; among other aspects (Sanchez & Valcárcel, 2000; Alves, 2018; Bego, Ferrarini & Morales, 2021; Zoca, Ferrarini & Bego, 2023).

To overcome these tendencies regarding teacher planning, the MDU is a planning model based on specific methodological conceptions and the implementation of multiple didactic strategies in an articulated, scientifically and pedagogically grounded manner. This proposal encompasses the conception of developing the design of didactic actions capable of meeting both teaching and learning purposes, as well as its implementation and, consequently, the analysis of learning.

The MDU proposal includes a set of 7 cohesive and interconnected tasks (Figure 1).

Figure 1

Tasks Proposed in the MDU.



Source: Bego, Ferrarini e Moralles (2021).

The tasks, objectives and procedures involved in planning an MDU are compiled in Table 1.

Table 1:

Tasks, Objectives and Procedures for Elaborating the MDU.

Task	Objective	Procedure
Context characterization	- To rationalize the context to be acted upon; - To identify the pedagogical practice restrictions; - To identify practical problems;	1. Characterize the school; 2. Characterize the class; 3. Characterize the students;
Scientifical and epistemological analysis	- To organize the structure of teaching contents; - To update teachers' scientific knowledge;	1. Select content; 2. Identify the conceptual or historical development of the main contents; 3. Define the unit's conceptual scheme;
Pedagogical and didactic analysis	- To determine the boundaries of learning: make it adequate to the student;	1. Investigate student's previous knowledge; 2. Determine the epistemological obstacles; 3. Make the teaching implications explicit.
Methodological approach	- To create awareness about the teaching and learning conception being used; - To make a vision of science explicit; - To define the purposes and expectations of Chemistry	1. Make the psycopedagogical principles of the methodological approach explicit; 2. Determine specific roles taken by the teacher and by the student in the teaching-learning process; 3. Define the goal of Chemistry

Task	Objective	Procedure
	teaching on a specific school level;	teaching in the formal educational environment; 4. Describe the vision of science defended and its implications to teaching;
Selection of the learning objectives	- To think about the students' learning potential; - To establish references of teaching and assessing;	1. Consider tasks 1 to 5 in conjunction; 2. Define priorities and organize them by importance;
Selection of pedagogical strategies	- To determine teaching strategies and the best structure and sequence; - To define which tasks are done by teachers and which ones are done by students;	1. Consider the methodological approach and the learning objectives previously determined; 2. Plan the global teaching sequence; 3. Select didactic strategies; 4. Elaborate the learning material; 5. Predict didactic resources needed;
Selection of assessment strategies	- To assess students learning; - To adjust and reorganize the teaching process; - To evaluate the MDU itself;	1. Determine the content for the assessment; 2. Determine the activities, plan in which moment they will be given to students and plan feedback; 3. Plan ways to collect data of the teaching-learning process.

Source: Bego, Ferrarini e Moralles (2021).

Due to the set of activities that encompass the perspective of implementing an MDU, it can be inferred that this project represents a potentially useful model of didactic-pedagogical intervention in terms of the teacher's professional action. This statement is mainly based on the expectation of a reflective teaching practice marked by pluralistic approaches. In regard to these pluralistic perspectives, Laburú, Arruda, and Nardi (2003) ratify the need for teachers to assume didactic actions based on methodological and didactic pluralism, as well as those directed towards reflective and dialectical movements.

Therefore, the use of the MDU provides the teacher with the possibility of adapting methodologies and teaching strategies to the school environment of interest, in terms of the specificities of the educational context and its current traits of complexity, singularity, and multidimensionality. Moreover, it is important to consider the relevance of proposing tasks based on theoretical frameworks capable of supporting teachers' didactic actions, as well as contributing to the improvement of professional practice (Silva et al., 2019; Ferrarini, 2020).

The MDU planning model foresees the link of a specific methodological approach to different didactic and assessing strategies, with the purpose to elaborate a coherent and integrated proposal in an organized and sequential manner.

In this logic, this work was organized around the planning of an MDU that was designed based on Inquiry-Based Teaching, according to the conceptions of Carvalho (2013). More specifically, this proposal was based on the methodological approach of Inquiry-Based Teaching. This is due to the fact that this teaching

methodology addresses perspectives that aim to improve the learning process, since there is the possibility of linking concepts to everyday life. The fore, the understanding of scientific themes can be facilitated by the possibility of creating situations of interest and motivation for students.

In the author's proposal, Investigative Teaching Sequences (ITS) are foreseen. In an ITS, interactions between students and the teacher constitute an important stage for knowledge construction. In this relationship, the teacher's role is to encourage students in the process of knowledge systematization through questioning and hypothesis elaboration. Among the positive aspects, it is identified that this investigative action is capable of, virtuously, promoting the incorporation of scientific language and the progressive abandonment of colloquial language based on common sense.

In a nutshell, the stages of an ITS include: i) the presentation of an experimental or theoretical problem that aims to introduce the scientific theme to the students; ii) to promote activities that aim to encourage the formulation of hypotheses; iii) to contextualize knowledge in the daily lives of students.

Regarding the theme of the MDU, which was implemented in a school in the countryside of São Paulo, it is pointed out that the proposal was based on an ITS directed toward teaching Substances and Mixtures.

The identification of the students' prior ideas regarding these curricular contents is presented by Furió and Dominguez (2007; 2012). As examples, it can be considered that:

• Students of basic education usually do not apply the macroscopic notions of substance to the concepts of pure and unmixed materials. In general, this group of individuals has the empiricist belief, reinforced by everyday language, that substances are mixed materials or products;

• In macroscopic terms, Spanish researchers state that students conceive the concepts of mixtures as identical to that of a compound substance;

• Generally, students' present the misconception that substances are the same thing as a simple substance. In this sense, the difficulty of understanding the submicroscopic nature of substances as a system formed by identical particles becomes evident;

• Students usually associate the formal concepts of substances and materials as synonyms.

• In macroscopic terms, students do not point out differences between the concepts involved in characterizing a mixture of simple substances and the elemental composition of compounds;

• Discussions about the submicroscopic nature of substances and mixtures are considered, by students, as something difficult to understand;

• Due to the lack of knowledge of the macroscopic meaning of substances, in contrast to the definition of mixtures, students are convinced that materials are mixtures constituted by simple, not very complex pure substances.

• Students conceive the idea that pure substances correspond to the opposite of "impure substances";

• Due to the macroscopic notion of the concepts of mixtures and compound substances, students, in general, believe that they have the same meaning, since there is confusion related to the bonds that can be established between different atoms.

As a result of what is presented in the cited reference, it is inferred that there is a need for not only the development of approaches capable of working with and advancing these understandings, but also the contemplation of conceptual requirements of these contents. For this reason, it is necessary to suggest a new format to approach this topic, aiming for an effective learning of students at this stage of schooling.

Given the importance of this subject, especially for learning subsequent topics in Chemistry, the use of new didactic proposals capable of incorporating new strategies that consider students' conceptions, experiences and interests, as well as the integration of conceptual, procedural and attitudinal content, is justified.

METHODOLOGY

Due to the purposes of this work, the principles of action research were employed. The basis for this decision comes from the intention of improving a practical action rather than necessarily developing new academic knowledge about a specific field (Moreira & Rosa, 2009).

As Tripp (2005) points out, action research consists of a strategy capable of promoting teachers' improvement regarding the use of their research in their teaching practice. Action research is conceived as a cyclical process (Figure 2) in which the activities of planning, implementation, description and evaluation are carried out.

Figure 2

Representation in four phases of the basic cycle of action research.

Source: Tripp (2005, p.446).

Action research is a methodological design conducted in cycles, with the purpose of being able to execute interventions after obtaining results from the link between theory and practice.

This perspective aligns with the perspective of implementing the MDU, since in this model there is a need to plan, carry out the didactic-pedagogical intervention and replan based on critical reflection on the intervention carried out, as it was previously mentioned (Bego, 2016).

This research comprises an excerpt from a master's dissertation in which a teacher that also acted as a researcher investigated her own pedagogical practice in a school in the countryside of São Paulo (Mendonça, 2020). The school is in a peripheral neighborhood adjacent to a forest and a water stream. The school serves students from the city itself and from neighboring cities. The class was composed of 15 students, most of whom had been studying at the school for years. All students were between 14 and 15 years old and only one of them was 17. With the agreement of the school coordination, as well as the free and informed consent of the students' parents or guardians, the MDU was implemented with the objective of analyzing and evaluating its impacts on teaching and learning processes.

The sources of information used were the participants, 9th-grade Middle School students; the teacher-student interactions that took place within the school's space and time; and, as documents, the research teacher's journals and the activities carried out by the students regarding the resolution of a case study, published by Mendonça et al. (2019), within the scope of the activities foreseen in the MDU.

Throughout the application of the MDU, the didactic-pedagogical interventions were filmed and transcribed with the intention of analyzing the interactions and occurrences that took place. According to Flick (2009), video analysis allows for non-verbal investigations about the participants, as well as records their actions and discourse in the contextualized environment.

For the analysis of the transcriptions of the dialogues, the Content Analysis (CA) method of Bardin (2016) was used. For the author, this tool allows the systematic, elucidative and deductive description of the collected data, therefore, contributing to the understanding of meanings that go beyond common speech and reading. In this process, there is the elaboration of a set of descriptive categories, through the articulation between sources and instruments. And, in view of this action, there is the possibility of determining valid and replicable deductions for a given analytical context, as well as the elaboration of interpretations for the research theme (Bego, 2013; Cavalcante, Calixto & Pinheiro, 2014; Bardin, 2016; Ferrarini, 2020). Due to space limitations and considering that the methodological procedures of CA are quite widespread in the field, further details of the step-by-step used can be obtained in Mendonça's master's dissertation (2020).

Following systematic criteria to recognize the consequences produced by the implementation of the MDU, analyses were undertaken following a Textual Analysis Guide (Bego, 2013). In addition, classroom journals were created and analyzed, given the relevance of this element for the actions of the teacher's professional practice, especially in the context of action research.

Finally, this research presents the number 59199416.6.0000.5400 for the Certificate of Presentation for Ethical Review (CAAE).

RESULTS AND DISCUSSION

The collected data were grouped, based on the CA categorization procedure. This was done in order to analyze the importance of students' alternative conceptions and their possible relationships with the development of the investigative methodology adopted in the MDU, as well as its implications for the teaching and learning processes.

In this logic, based on Carvalho's (2013) proposals for Inquiry-Based Teaching, the presented MDU contains an ITS of 4 lessons (Table 2).

Table 2

Excerpt from the MDU planning on water pollution.

TITLE, LEARNING OBJECTIVES AND DIDACTIC SEQUENCES			
Title	**Water Pollution**		
Objective	To analyze different materials, in order to differentiate a pure substance, a simple substance, a compound substance and a mixture, using case studies.		
Investigative Teaching Sequences	**Objective**	**Content**	**Approximate time (number of classes))**
The fish out of the water	Analyze different types of water, differentiating substance from mixture	• Concept of system; • Concept of substance and mixture; • Concept of drinkable water and pure water;	4 classes

Source: Mendonça (2020).

In the ITS (Table 3), the proposal is to indicate to students the investigation of different types of water and, consequently, the difference between substances and mixtures.

Table 3

Excerpt from the MDU planning for SD 1.

SELECTION OF DIDACTIC STRATEGIES AND ASSESSMENT STRATEGIES	
Title of the Investigative Teaching Sequence	**The fish out of the water**
Objetive	To analyze different types of water, differentiating substance from mixture
Assessment Strategies	Case resolution and applied exercises

SELECTION OF DIDACTIC STRATEGIES AND ASSESSMENT STRATEGIES		
Class	**Didactic Strategies**	**Teaching Content**
Class period 1 and 2	Case Study	Substance and Mixture
	Debate	Substance and Mixture

Source: Mendonça (2020).

As Table 3 shows, the first didactic strategy used was the Case Study. The intention of this action was to provide active participation from the students in their respective learning, as well as to offer ways to investigate socio-scientific aspects related to different types of water. More specifically, the case is designed in the form of a narrative, and it involves everyday problems, concrete or imaginative, experienced by people who demand decision-making on previously chosen issues (Sá, Francisco & Queiróz, 2007).

Inquiry-Based Teaching was adopted for the planning of the MDU, as a methodological proposal for teaching and learning didactic actions. The Case Study was designed to develop the first two stages of the selected investigative methodology: i) problematization; ii) group discussion to raise hypotheses.

The problem-solving followed the sequence of an ITS. In the problematization phase, the case "The Fish Out of Water" by Mendonça et al. (2019) was presented. In this phase, the investigation was mediated by the teacher, given that there was both a need for guidance in conducting research and for establishing which search websites could be used to find reliable information.

After the schematization of the obtained information, the process of collective systematization of the information started. This activity involved the presentation of reflections and notes made by students. Subsequently, the teacher formulated questions to promote a debate based on scientific arguments; the questions intentions were related to the validation of the research undertaken. The final stage of systematization involved individual work by the students and resulted in a written record of the knowledge acquired.

To finalize the ITS proposal, students are encouraged to contextualize their knowledge, supported by the case narrative. This happened because the story used in the case is embedded in the students' social context and has the potential to stimulate them to relate scientific content to everyday life, as well as to apply it in their daily lives.

As already mentioned, the arguments related to this topic can reveal different alternative conceptions. In this sense, the works of Furió and Dominguez (2007, 2012) were used to anticipate possible learning obstacles that students might encounter during the didactic activities.

Moreover, the intention of using the case was related to the purpose of developing the concepts of substance and mixture based on the three aspects of chemical knowledge: the phenomenological, the theoretical and the representational. More specifically, the phenomenological aspect addresses the empirical aspect of chemical knowledge (observations and measurements). The theoretical perspective comprises the set of explanations based on models and theories. And, finally, the representational aspect consists in chemical language,

that is, symbols, formulas and representations (Mortimer, Machado & Romanelli, 2000).

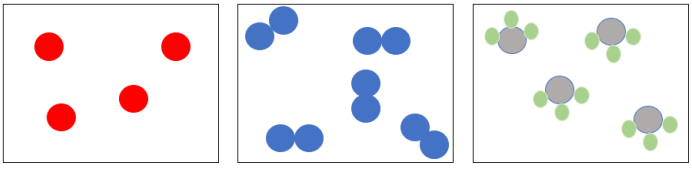
In the phenomenological aspect, substances can be defined as a fraction of material that presents constant physical properties and that has a chemical composition that does not vary from sample to sample. A mixture is composed of different substances in which each one maintains its own chemical identity and, thus, its peculiar physical properties. Thus, mixtures present, as a characteristic, non-constant physical properties (Lacerda, Campos & Marcelino, 2012).

Regarding the theoretical aspect, it is stipulated that substances are systems with a defined chemical composition, formed by a single type of chemical species that repeats throughout the entire system. Mixtures, on the other hand, contain two or more chemical species in their constitution and are classified as systems that do not have a defined chemical composition (Brown, Lemay & Bursten, 2005; Bellas et al., 2019).

In representational terms, a substance comprises a fraction of matter that presents only one chemical component, as illustrated in Figure 3. According to the mentioned image, in each square, the spheres can be arranged in an isolated manner or in fixed combinations.

Figure 3

Representation for various varieties of substances.

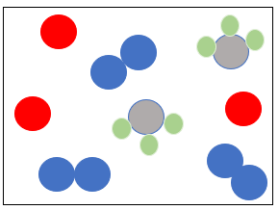


Fonte: Adapted from Brown, LeMay & Bursten (2005, p. 5).

From the same point of view, a mixture is defined as a portion of matter where different types of substances coexist together. Figure 4 presents different types of substances that are portrayed by spheres with different colors in distinct aggregates (Rocha-Filho et al., 1988; Santos & Mól, 2016).

Figure 4

Representation of a mixture.



Fonte: Adapted from Brown, LeMay & Bursten (2005, p. 5).

The theoretical links between different types of water and their relationship with the concepts of substances and mixtures represent the potential of the mentioned case study. This is due to the fact that the problematic situation presented by the case allows students to explicitly state possible alternative

conceptions about the types of water (pure, drinkable and polluted) and formulate hypotheses for the best type of water to be used in an aquarium.

As Furió and Dominguez (2007) point out, students tend to confuse the concepts of substance and mixture. Among the inconsistencies demonstrated, the ideas that stood out were: only heterogeneous mixtures are associated with the concepts of mixture, given that homogeneous mixtures, which have only one phase, would be substances; the inability to conceptualize substance as a submicroscopic system formed by particles or an aggregate of equal particles, resulting in the idea that any substance is classified as simple; the conception of the occurrence of impure substances, resulting in the lack of knowledge of the notion that any mixture of substances already characterizes a given system as a mixture.

Students' Conceptions of Substances and Mixtures

In the first part of the ITS, students, in groups, presented their initial hypotheses about which type of water (pure, drinkable and polluted) would be the best to use in the aquarium to keep the fish alive.

Given this context, the importance of CA of the hypotheses formulated, regarding the concepts of substances and mixtures, is justified, in order to reveal students' alternative conceptions for this topic. The different types of hypotheses were grouped into analytical categories considering the correct and incorrect hypotheses (Table 4). These categories were formulated considering the position of the 11 students present on the day the ITS was applied; the students were divided into groups of 1 pair and 3 trios.

Table 4

Results obtained from the analyses of students' prior responses.

Categories	Justification	Representative Extracts	Count
Physical-chemical treatment criteria	In this category, the answers that used physical chemical treatment on the water, are grouped together	“Drinkable water: water that has been through a ‘cleaning’ process to be consumed or used in other activities, such as agriculture” (1) “Pure water: clean water, that has no pollutant residues; the water receives no treatment”” (2)	2 (50%)
Classification based on the water’s source	In this category, the answers that used different sources of water, are grouped	“Drinkable water: water that we drink; it is treated and it is normally found in gallons and water bottles” (3) “Polluted water: water found in sewers; this water is inadequate to life, because it contains dangerous substances, pollutants and harmful residues that can jeopardize human health ” (4)	3 (75%)
Natural purity identification	In this category, the answers that classify the water as natural or	"Pure water: water in its natural state, without cleaning processes or any other factor” (5) "Pure water: water found in water	3 (75%)

Categories	Justification	Representative Extracts	Count
	‘pure’, are grouped	springs; ideal for natural life"(6)	

Fonte: Mendonça (2020).

The definitions presented by the groups show relation with the alternative conceptions found in literature, described by Furió and Dominguez (2007; 2012).

The first conception that can be observed is presented in the representative extracts 1 and 2, which exhibit the alternative conceptions concerning the classification of water types (pure, drinkable and polluted). In this context, the importance given to the physical-chemical criteria for carrying out the classification becomes explicit. Using this type of ordering, it is inferred that students link macroscopic characteristics only to processes such as, for example, water treatment.

In the representative extracts 3 and 4, the alternative conception related to the characterization of a mixture is manifested. Students use the criteria “from different sources” to classify the types of water, that is to classify as drinkable or polluted, it is enough to know the source. Furthermore, students believe that only polluted water is classified as a mixture because, for them, at the macroscopic level, this type of water presents more than one phase, which, in turn, is constituted by visible contaminants. Thus, it is understood that, at the macroscopic level, a mixture is a system that has more than one phase, that is, a mixture is always associated with a heterogeneous mixture.

Furthermore, examining the representative extracts 5 and 6 and relating them to the conceptions gathered by the Spanish authors, it can be inferred that students do not conceptualize substance as a system formed by equal particles. In other words, for students, drinkable water, having only one visible phase, would be characterized as a pure substance, although it is a homogeneous mixture.

Students' Conceptions after the Investigative Teaching Sequence

Considering the development of the stages of Inquiry-Based Teaching (Carvalho, 2013), the students were organized again into groups to research the definitions of the terms used during class. This search was conducted by the students using tablets connected to the internet.

At this moment of the ITS, students verified the validity and adequacy of their initial hypotheses. If the hypotheses presented inaccuracies regarding the scientific terms, the students would have the opportunity to reformulate their initial responses and express them again to the group. For Carvalho (2013), this consists of an important stage for learning.

The data generated by this action were grouped and analyzed. The scientific conceptions researched were divided into correct and incorrect hypotheses. In this case, the correct answer would be the classification of the ideal water for the fish as drinkable water. The result obtained was 100% for correct hypotheses.

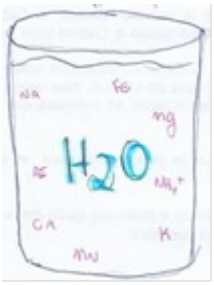
Thus, confronting the data from the previous and subsequent versions, it is evident that, in the initial hypotheses, only one group had answered correctly from

a scientific point of view. In this sense, it is possible to understand that there is a clear perception that, at least in its formal expression to solve the case, students altered their initial ideas (in which they assumed pure water as the ideal for the fish, since it would be free of residues).

It is important to highlight the fact that research was carried out not only to obtain the case's answer, but also to obtain terms that classify water quality (Table 5).

Table 5

Count of students' responses and representative excerpts of each categorization.

Scientific terminology	Representative Extracts	Representation	Count
Drinkable water	"It is the one that receives specific treatment to residences. It is composed by minerals that are not harmful to human health, such as: Na, K, Ca, Mg, Fe, Mn. (7)" "It is all the water that is proper for consumption. No water is only formed by H_2O. There are also salts dissolved in this water, such as sodium chloride, among other substances. Drinkable water may contain other substances, but they are not harmful." (8)		4 (100%)
Pure water	"It is the water that is composed by H_2O only. There are no more substances included in it" "Pure water (distilled) is completely free of other substances, meaning that there is only H_2O." (9)		4 (100%)
Polluted water	"It is the water that has physical-chemical alterations to it. If the water has a different odor or color, it can be known that it is polluted. However, the color and bad smell can be provoked by unharmful substances to men." (10)	There were no representations	4 (100%)

Fonte: Mendonça (2020).

Based on the data obtained, it can be inferred that, despite the correct description of the term drinkable water, none of the groups expressed the relationship between this term and the concept of a mixture. However, it is observed that there is an intention to represent this system as a group of chemical entities. Therefore, even though they did not use the term mixture, they correctly classified what drinkable water would be, making its difference from pure substance perceptible (extracts 7, 8, and 9).

Moreover, the comparison between the extracts highlights the ability to differentiate the terms pure, drinkable and polluted water (extracts 7, 8, 9, and 10). In this sense, the way of describing the term polluted water stands out because,

although the description is correct, it is observed that, once again, students do not reach a final classification using chemical language, classifying it as a mixture (extract 10).

On the other hand, throughout the didactic and pedagogical actions of the teacher, there was recognition by students of which systems were mixtures. In this situation, even though students did not use these terms to describe the different types of water that exist, the acquisition of conceptual content of the topic addressed is manifested.

Certainly, this confirms the acquisition of knowledge regarding the need to verify the components within the systems to characterize them. Moreover, based on the descriptions of Furió and Dominguez (2007), it is explicit that investigative teaching activities were crucial for students to navigate through different representations of chemical knowledge, allowing for progress in relation to initial alternative conceptions.

It is understood that the findings of this research seem to be expressive when comparing the complexity of the dimensions involved in implementing an alternative planning model to purely transmissive teaching perspectives.

Thus, it is assumed that the application and reflection on the implementation of the MDU is potentially useful for bringing the theoretical and practical actions of a teaching methodology closer together, as well as for involving meta-knowledge of the teacher's professional practice for the elaboration of teaching and learning activities (Ferrarini, 2020).

FINAL CONSIDERATIONS

This action research involved the implementation of an MDU that encompassed the application of an investigative teaching methodology based on ITS.

As the presented data shows, the methodology based on Inquiry-Based Teaching provided Middle School students with moments of reflection and autonomy for the construction of scientific knowledge about substances and mixtures linked to their daily lives.

Regarding the didactic and pedagogical actions of the MDU, the identification of alternative conceptions of student groups regarding substances and mixtures stands out. These perspectives were related to: the notions that pure water corresponds to a material free of residues; the macroscopic criteria that are responsible for identifying the type of water; the conception that mixtures are systems with more than one visible phase and that, consequently, polluted water is a mixture; the idea that pure and drinkable water would be the same thing, since there were no considerations regarding the submicroscopic criteria to differentiate them, that is, the term pure was associated with purity and cleanliness.

These prior conceptions were part of the actions involved in the use of ITS and provided relevant data to ensure the validity of the tasks proposed for the consolidation of the didactic-pedagogical planning, as well as the effectiveness of student learning. In other words, the empirical data compiled, after stages 3 and 4

of the ITS, points to significant advances of these conceptions toward current scientific concepts.

Finally, the implementation of the MDU, founded on an action research perspective, proved to be a relevant way for the researcher teacher to address the concepts related to the theme of substances and mixtures, as the proposal encompasses multi-strategic planning and ample moments for reflection on their practice. With regards to the didactic-pedagogical intervention, a Case Study and other complementary strategies were used, and the mentioned conceptual content was articulated around a lesson plan capable of providing students with an opportunity to dive deeper into scientific knowledge, as well as to offer them tools of science for future autonomous investigations and experiences of collaborative group work.

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