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Planning Teaching Sequences Based on Problem-Solving from a Scientific Dissemination Tool

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ABSTRACT

Background: The problem-solving approach has been highlighted in chemistry teaching. **Objectives**: To analyse the theoretical-methodological adjustments on the problem-solving approach carried out by chemistry teachers in their teaching plans. **Design**: Carrying out a problem-solving training activity. **Setting and participants**: This research involved twenty basic chemistry teachers, students of the professional master's degree course in chemistry in the national education network offered by the Federal Rural University of Pernambuco. **Data collection and analysis**: We used the content analysis technique through *a priori* and *a posteriori* categories to analyse the teachers' plans built from guiding studies published on the RPEQ website. **Results**: We noticed that the teachers used few elements as presented in the guiding studies, building different plans according to their classroom contexts and demonstrating autonomy and creativity. **Conclusions**: We observe the potentiality of the RPEQ website regarding its functionality as a digital didactic resource serving as a basis for teachers to plan teaching situations that are different from the traditional method.

Keywords: Problem-solving; Chemistry teaching; Scientific dissemination; RPEQ website.

Planejamento de sequências de ensino baseadas na resolução de problemas a partir de uma ferramenta de divulgação científica

RESUMO

Contexto: A abordagem de Resolução de Problemas vem se destacando no âmbito do Ensino da Química. **Objetivos**: Analisar as adequações teórico-

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metodológicas sobre a abordagem de Resolução de Problemas realizadas por professores de Química em seus planejamentos de ensino. **Design**: Realização de uma atividade formativa sobre Resolução de Problemas a partir de um suporte de Divulgação Científica – *Website* RPEQ (Resolução de Problemas no Ensino de Química). **Ambiente e participantes**: Participaram desta pesquisa vinte professores de Química da Educação Básica discentes do curso de Mestrado Profissional em Química em Rede Nacional oferecido pela Universidade Federal Rural de Pernambuco. **Coleta e análise de dados**: Utilizamos a técnica da Análise de Conteúdo por meio de categorias *a priori* e *a posteriori* para analisar os planejamentos dos docentes construídos a partir de Pesquisas Norteadoras divulgadas no *website* RPEQ. **Resultados**: Percebemos que os docentes utilizaram poucos elementos tal como apresentados nas Pesquisas Norteadoras construindo planejamentos diferentes de acordo com seus contextos de sala de aula demonstrando autonomia e criatividade. **Conclusões**: Observamos a potencialidade do *website* RPEQ concernente a sua funcionalidade de recurso didático digital servindo como base para que os docentes possam planejar situações de ensino diferentes do método tradicional.

Palavras-chave: resolução de problemas; ensino de química; divulgação cientifica; *website* RPEQ.

INTRODUCTION

The problem-solving (PS) approach has been gaining prominence in the chemistry teaching field, consolidating itself as a line of research in the area (Schntezler, 2002; Leite & Esteves, 2005; Freire, Silva Júnior, & Silva, 2011; Fernandes & Campos, 2017; Freitas & Campos, 2021a), as it favours the construction of chemical knowledge and the formation of critical and reflective citizens through problems that place students in their historical, sociocultural, and economic context.

From the 1990s to the present day, we can say that there has been significant growth in research involving the proposition of problems in chemistry as a baseline for learning. This is due to the satisfactory learning results that have been obtained, associated with the elaboration, use, and development of didactic instruments as a means of supporting students to take a stand in the face of the proposed problems (Freire & Silva, 2013; Lima, Arenas & Passos, 2018; Medeiros & Goi, 2021; Goi & Santos, 2014).

However, although several works in the literature involve PS directed at chemistry teaching, few basic education teachers have heard of them. In addition, their contributions to improving the teaching and learning process have not reached high school chemistry classes, as stated by Freitas and Campos (2018), corroborating the results of Schnetzler's research (2002). This is because universities have carried out little scientific dissemination (SD) activities (Torresi, Pardini & Ferreira, 2012; Freitas & Campos, 2018), mainly regarding the dissemination of research carried out in the field of the didactics of science. Indeed, this distance between higher education and basic education institutions is a problem that researchers in this area must seek to solve.

With this problem in mind, the website on PS in chemistry teaching (RPEQ website) aims to systematise the research carried out on the matter and, based on it, to promote the SD of these studies to basic education chemistry teachers. The teachers participating in this study reported that they are unaware of research in chemistry teaching that universities have developed.

Most investigations published on the RPEQ website, which can be accessed through the electronic address http://www.rpeq.ufrpe.br, were developed by professors and researchers from the RPEQ (Resolução de Problemas no Ensino de Química) [Problem Solving in Chemistry Teaching] research group at the Federal Rural University of Pernambuco (UFRPE), as a result of projects developed by students of the postgraduate studies in science teaching (PPGEC-UFRPE), the professional master's degree in chemistry (PROFQUI-UFRPE), and the scientific and teaching initiation programs at UFRPE. Besides research produced in UFRPE, the website also has research carried out by research groups from other universities, such as the Federal University of Rio Grande do Norte (UFRN).

Moreover, Freitas and Campos (2017) evidenced that chemistry teachers working in basic education present simplistic ideas of the theoretical-methodological knowledge of the PS approach that are relevant to the development in class, such as the conception that PS only promotes the contextualisation of the chemical content without knowing the difference between a problem and an exercise. In this way, teachers' understanding of this knowledge is important so that they can appropriate the research and its results published on the RPEQ website and use/adapt them in their school context to promote a more contextualised teaching, a teaching that makes more sense for the student.

Indeed, for teachers to be able to work with PS in class, they must know chemistry teaching practice in the sense of knowing how to plan activities for development in the classroom based on PS. Therefore, it is also relevant to discuss the importance of lesson planning and developing teaching sequences that help in the teaching and learning process.

Despite PS contributing significantly to teaching and learning chemical content, investigations into PS aimed at teacher education, particularly in the continuing education of chemistry teachers, are still incipient in the national and international scenario (Freitas & Campos, 2021a), the same as for the SD theme discussed in the teacher education directed to chemistry teaching (Freitas & Campos, 2021b).

Based on the considerations above, this investigation consisted of proposing a formative process for basic education chemistry teachers on PS aimed at chemistry teaching based on the theme of the SD and the RPEQ website. We envisage answering the following research question: What are the theoretical-methodological adaptations of the PS established by the teachers when using the RPEQ website as an SD tool in their plans? Thus, our research objective was to analyse the theoretical-methodological adjustments made by basic education chemistry teachers in their teaching plans after participating in a continuing education process on the problem-solving approach based on scientific dissemination support – the RPEQ website.

CONTINUOUS EDUCATION OF CHEMISTRY TEACHERS

Carvalho and Gil-Perez (2011) present training needs that should be addressed, whenever possible, in the initial or continuing education of science/chemistry teachers. Among them is *Knowing how to prepare activities that generate fruitful learning* and *Knowing how to direct students' work.* For the development of this study, we focused on these two needs, as our training was directed towards the construction of teaching plans based on the PS approach by chemistry teachers based on the SD of research in this line.

Knowing how to prepare activities that generate fruitful learning is a basic and essential formative aspect that must be worked on throughout chemistry teachers' careers (Gil-Perez & Carvalho, 2011). About this formative need, the authors emphasise that one should discuss with the teachers different teaching strategies in the perspective of organising students' learning of chemical contents through the construction of knowledge. Therefore, it is not just a question of preparing some "random" activities but planning the development of themes through activities students would carry out. Thus, it is necessary to work with teachers on teaching plans based on strategies that enable the development of a sequence of activities to achieve the established learning objective(s).

Gil-Perez and Carvalho (2011) point out as a suggestion of a constructivist teaching approach the use of problem-situations or also called just problems, in which they are contextualised and should be the starting point for learning and which advocates the performing a sequence of activities to solve the problem (Pozo, 1998; Leite & Esteves, 2005; Souza & Dourado, 2015). When planning based on the PS approach, the teacher plays a different role from traditional teaching (knowledge transmitter), becoming a guide during the teaching and learning process.

From this perspective, Gil-Perez and Carvalho (2011) highlight the training need for *Knowing how to direct students' work*, which is directly correlated with the previous need. When proposing learning from problem situations, the teacher needs to: know how to properly present the activities to be carried out by the students, allowing them to have an overview of the task and to be interested in it; know how to direct activities in an orderly manner and create and manage the functioning of groups and the exchange of knowledge between group members; carry out syntheses and reformulations of ideas that value students' contributions and duly guide the development of the task; create a good atmosphere for the class to function and a good relationship between teacher and student and the school; and demonstrate interest in each student's activity and progress. Therefore, discussing this "new" conception of the teacher's role in student learning with chemistry teachers is relevant.

THE PROBLEM-SOLVING APPROACH

Teaching directed to problem-solving presents different terminologies, such as problem situation (PSit), problem-solving-based learning (PSBL), or problem-based learning (PBL). However, regardless of the designations and possible conceptual divergences that may exist between them, they are all directed towards the same purpose: to promote students' active participation in the teaching and learning process, specifically on the assumption that students learn by doing (Leite & Afonso, 2001; Leite & Esteves, 2005), and thus enable learning that is meaningful to them. In this context, students learn by solving problems or problem situations, which act as a stimulus, motivation and starting point for learning.

In the literature, we find PS being worked on in the classroom in two directions: to guide the curricular development of a subject or course, in which the problems are used as criteria to discuss all subject contents, as proposed by Barrows and Tamblyn (1980) with the name of PBL, or to occasionally work on some subject contents, such as a methodology, teaching, and learning approach, or didactic approach, usually used in isolation in a subject, called PS (Pinho, 2017). Thus, we will use the PS in the context of this last perspective because we consider the problems as a starting point for learning, contextualised with the syllabuses occurring more occasionally in the classroom, the research context of PS used in research carried out by the Nucleus for Research in Teaching and Learning Based on Problem-Solving (Núcleo de Pesquisa em Ensino e Aprendizagem baseado na Resolução de Problemas - NUPEABRP) at UFRPE.

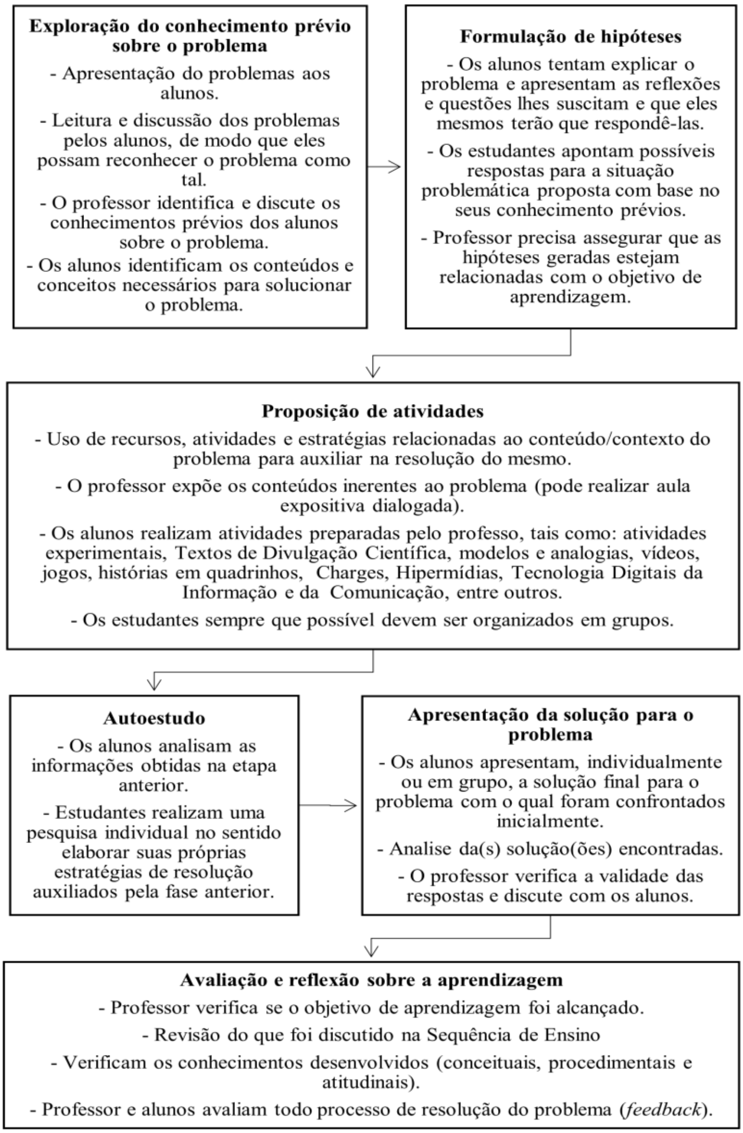
According to Marques and Cunha (2022), the definition of PS as an approach or methodology reflects the didactic actions, which, in turn, contemplate the methodological practice, which involves theoretical assumptions about teaching and learning and the relationships between teacher and student. PS incorporates methods, strategies, tools, and resources (instruments) to achieve the learning objectives. Therefore, by qualifying PS as a teaching and learning approach in this research, we aim to provide teachers with knowledge about it and enable its use in chemistry classes as an alternative to diversify their classes, providing students with more effective learning of chemical content.

Delman and Hoeberigs (2009) present three fundamental PS characteristics: to provide *constructive learning*, *contextualised learning*, and *collaborative learning*. *Constructive learning* consists of constructing new knowledge based on existing knowledge; that is, it involves understanding new information, taking into account students' prior knowledge. *Contextualised learning* involves integrating elements of knowledge seen in the classroom with everyday reality. Thus, if new knowledge is learned meaningfully and linked to a context when the student needs this information in the future, access to it and its recovery will be facilitated. Regarding *collaborative learning*, the authors explain that social factors also influence learning. In this way, the work carried out in small groups exposes students to various points of view on a given subject. In this sense, the PS approach has as one of its assumptions to provide group activities to solve problems.

The implementation of PS in the classroom occurs through the planning and application of a teaching sequence (TS), which consists of different steps, dynamics, and activities that will be proposed to students to solve the problem. Thus, in a TS directed towards the PS approach, students are initially confronted with a problem or problem situation, which is the starting point for learning. In this way, students will acquire knowledge through strategies and resolution activities to understand the chemical concepts underlying the proposed problem (Engel, 1997; Leite & Afonso, 2001).

Figure 1

Methodological guidelines for planning teaching sequences based on the problem-solving approach.



We mapped the literature on the methodological aspects composing the PS and observed that the authors' proposals converge in many factors, such as: starting learning activities by confronting students with a problem; raising hypotheses; the definition of the problem by the students, recognising it as such; the use of didactic resources to help them in the search for a solution; promotion of group activities to favour teacher-student and student-student interaction; presentation of the solution (or not) for the problem after the participation of the students in the steps that precede the exposition of the final answer; and the evaluation, both in relation to the pertinence of the answers presented and the analysis of the entire process developed, observing the conceptual, procedural, and attitudinal knowledge that could be built throughout the TS (Meirieu, 1998; Pozo, 1998; Leite & Afonso, 2001; Souza & Dourado, 2015).

Based on these discussions, we proposed a sequence contemplating, in general, the methodological aspects pointed out by the referenced researchers to provide teachers with guidance for constructing their teaching plans and implementing this approach in the classroom. The sequence is shown in Figure 1.

METHODOLOGY

The methodological orientation of this investigation was anchored in qualitative research (Oliveira, 2016). The participants of this study were the postgraduate students of the professional master's degree in chemistry in the national education network (PROFQUI) offered by a pole of a higher education institution - UFRPE. The choice for these subjects was because the course is extended only to teachers with a degree in chemistry. Thus, twenty (20) teachers participated in this research. All participants signed the Free and Informed Consent Form. This study was submitted to the Research Ethics Committee (CEP), identified by number 51790621.4.0000.9547 of opinion number 5.109.027.

To reach the established objective, we carried out a process of continuing education with these teachers about the PS approach and the SD theme, both directed to chemistry teaching. We intended to help these PROFQUI students build a teaching plan based on PS from the SD of research developed in this direction made available on the RPEQ website.

The formative activity was carried out during the pandemic caused by the coronavirus disease (covid-19); therefore, the meetings took place remotely on the topic *Seminários Web 4.0* offered by PROFQUI with the following title: "*A Divulgação Científica e a abordagem de ensino por Resolução de*

Problemas no ensino de Química" [*Scientific dissemination and the problem-solving teaching approach in chemistry teaching*] with a total workload of 15 hours. Weekly meetings were held, totalling five (5) classes organised in synchronous and asynchronous moments.

All meetings were videotaped to aid in data analysis. In class 4, the teachers were invited to get organised in five (5) groups to build a TS based on the PS from the SD of research in the area using the RPEQ website. Thus, three groups were left with four members; one group of five members and one group of three members.

Data analysis

Our analysis materials were the teaching plans (the TS) prepared by the groups of teachers during the training activity and the recording of their presentations. Both materials were analysed according to the content analysis (CA) proposed by Bardin (2011). The author suggests that the analysis be organised into three sequential phases: *Pre-Analysis*; *Exploration of the material; Treatment of results, inference, and interpretation.*

At *Pre-Analysis*, after the data collection, we organised the materials by coding the plans, which were identified according to the groups that did so, henceforth called G1 to G5. We transcribed the recording of the presentations of the groups of teachers, skimmed the reading (short reading) of the TS and selected the theoretical framework on PS that would support the analysis.

In the phase of *Exploration of the material*, data encoding and categorisation derived from detailed readings are carried out *from* the registry units (or units of meaning), key terms in the analysed materials. Context units express the context in which the registry units were found. According to Bardin (2011), categories can be defined before data analysis (*a priori*) and after analysis (*a posteriori*).

For the analysis of the teachers' teaching planning, we used *a priori* categories, as we intended to analyse the theoretical-methodological adjustments on the PS approach for chemistry teaching, which the teachers carried out, since their planning was based on the research available on the RPEQ website. Such categories were based on PS assumptions (Pozo, 1998; Meirieu, 1998; Leite & Afonso, 2001; Delman & Hoeberigs, 2009; Souza & Dourado, 2015). Beyond the *a priori* categories, we also identified *a posteriori* *category,* classified as Category A. The other categories were named B through H and coded according to the subcategories described in Table 1.

Table 1

Categories and subcategories of analysis of the theoretical-methodological adaptations of the problem-solving (PS) approach carried out by the professors

Categories	Subcategories (PS theoretical-methodological adaptations)	Analysis Code
A. Teaching modality	1. Classroom Teaching	A1
	2. Adaptation for remote teaching	A2
B. Contents	1. New Content	B1
	2. Same Content	B2
	3. Insertion of Content	B3
C. Thematic	1. New Theme	C1
	2. Same Theme	C2
	3. No Theme	C3
D. Objectives	1. New objectives	D1
	2. Adapted objectives	D2
	3. Identical objectives	D3
E. Problem	1. New Problem	E1
	2. Adapted problem	E2
	3. Identical problem	E3
F. Dynamics of activities	1. Sequence of identical activities	F1
	2. Adaptation of the sequence of activities	F2
G. Activities and resources	1. New resources and activities	G1
	2. Identical activities	G2
	3. Adaptations of resources and activities	G3
H. Survey of previous conceptions	1. New previous questions	H1
	2. Adaptation in previous questions	H2
	3. Identical previous questions	H3

The last phase, *Treatment of results, inference, and interpretation,* refers to the treatment of the results of document analysis in a way that will be meaningful and valid. To do so, we made inferences and interpreted the data according to our theoretical framework regarding the PS approach and used tables to systematise the results, as suggested by Bardin (2011).

RESULTS AND DISCUSSION

To reach our objective, we analysed the TS prepared by the teachers and compared them with the guiding studies (GS) available on the RPEQ website, which they used to build their plans to verify the theoretical-methodological adaptations of the PS approach they carried out when using the RPEQ website as a digital didactic resource to prepare their classes. Table 2 lists the title of the GS used by each group and the title of the new sequence the teachers created.

Table 2

Title of surveys on the RPEQ website used by the groups of teachers to prepare their plans

Group	Guiding Studies (GS) from the RPEQ website used by teachers	Title of the new teacher planning
G1	Abordagem dos Conceitos Mistura Substância Simples, Substância Composta e Elemento Químico numa Perspectiva de Ensino por Situação-Problema [Approach to the concepts mixing simple substance, compound substance and chemical element from a perspective of teaching by problem-situation] (Lacerda, Campos, & Marcelino-JR, 2012).	Approach to the concepts that involve chemical reactions in the daily life of high school students.
G2	Situação-Problema como Estratégia Didática na Abordagem do tema Lixo [Problem-situation as a didactic strategy in approaching waste as a theme] (Silva, Fernandes, & Campos, 2014).	A title was not displayed.
G3	Uma Abordagem do tema Biodiesel no Ensino Médio utilizando uma Situação-Problema [An approach to the biodiesel theme in high school using a problem-	An approach to the biodiesel theme using a problem-situation in a high school in the hinterland of Paraíba.

	situation] (Rodrigues, Morais, Simões-Neto, & Silva, 2015).	
G4	A abordagem de Ligação Química numa Perspectiva de Ensino por Situação-Problema [The chemical bonding approach from a teaching perspective by problem-situation] (Fernandes & Campos, 2013).	A problem situation in the approach to teaching chemical bonds for 1st-grade high school students.
G5	Sequência Didática Baseada na Resolução de Problemas para a Abordagem de Cinética Química [Sequence based on problem solving for the approach to chemical kinetics (Sales & Batinga, 2017).	A title was not displayed.

When the teachers were preparing the TS during the training activity, we did not indicate a model for building their plans; instead, we let them browse the RPEQ website as they pleased to choose the studies that would focus on building their plans. Thus, the searches available on the website were the starting point for the teachers and their groupmates to analyse, discuss, and reconstruct these works considering their classroom contexts.

We chose to analyse the adaptations since each search on the website was developed for a specific context, which may not be consistent with the reality of the classroom context of our research subjects. In this sense, the participants were instructed to adjust their plans according to their current classroom context, unable to replicate a study (a TS in full) contained on the RPEQ website. Thus, they should carry out their plans *from* one (or more) research works present on the website and inform which one(s) were used to support their plans. They could still fully utilise some elements of existing TS; they could adapt them or build a new one.

Appendix A presents the results found for each category listed in Table 1. The subcategories are related to the theoretical-methodological adaptations of the PS that we observed in the TS constructed by each group. In the field of registry units is the description of the subcategories and the underlined words concerning the units of meaning. The field of context units refers to some representative excerpts as they were found in the analysis material (transcription of presentations, PowerPoint file and organisation of the sequence) and the GS sequences, highlighting the units of meaning (underlined words). The mentions made in square brackets represent speeches and situations perceived during the presentation of the groups. The codification that relates the groups to the categories and subcategories is described in the analysis code field.

As the teacher's first theoretical-methodological adequacy, we highlighted Category A referring to the teaching mode chosen by the groups, being the only category that was determined *a posteriori*, that is, defined after the analysis of the plans. Thus, we identified that G2 chose to present a teaching proposal in the remote modality (Subcategory A2), in which all activities and meetings between students and the teacher would be carried out virtually through *Google Meet* and *Google Classroom*. The proposal for this teaching modality was due to the pandemic context caused by covid-19, when schools and universities had to carry out their activities remotely. The research data was collected during this period.

The other plans were designed to be in-person (G1.A1, G3.A1, G4.A1, G5.A1). In this sense, the problem and the activities proposed in the research of the RPEQ website can be adapted for a remote teaching situation. In cases where there is an experimental activity, for example, it is possible to choose to perform it through digital resources (Leite, 2015), through experiments of the demonstrative-investigative level as proposed by Silva, Machado, and Tunes (2019), which do not require the physical space of the laboratory.

Regarding categories B and C, we aimed to identify the adaptations made to the content and theme chosen by the teachers. Most teachers proposed a TS using the same content and theme as the GS (G2.B2. C2, G3.B2. C2, G5.B2. C2).

On the other hand, G1 was the only group that did not use the same content and the same theme as the GS, even though the RPEQ website provides a search on chemical reactions (chemical content chosen by the group), as was the option of G2.B2, G1 chose not to use it, just as it did not use its theme. Therefore, it was possible to infer that the G1 teachers preferred not to prioritise the content or a theme but to build their planning based on a survey of the RPEQ website that contemplated the methodological aspects of PS to aid in understanding how to plan didactic situations based on this teaching approach.

The G4.B3. C3, in turn, used the same content of chemical bonds as the GS but added the discussion of the concepts of covalent bonds, which was not addressed in the study of the RPEQ website (Subcategory B3) and did not propose the discussion of a theme (Subcategory C3).

Furthermore, it was possible to observe that no group chose to discuss, in their teaching planning, a theme different from that addressed by the GS

(Subcategory C1). In this sense, we understand that planning classes based on the discussion of a theme can be an obstacle for teachers, especially when it comes to the PS approach, as pointed out by Freitas and Campos (2021c), as it may require teachers' research and study time to go deeper into a specific topic, in the sense of relating the chemical contents with social, political, economic, and cultural situations. The researchers point out that because this teaching approach requires the proposition of a problematic scenario, which must address a real situation that has already occurred and/or may occur in the student's daily life and their social, cultural, historical, and economic context, it needs, therefore, time for the teacher to construct a problematic situation in which there is no immediate solution and which differs from the exercise.

Regarding the analysis of adequacy relevant to the objectives (Category D), we found that G1 and G5 were the only groups to present objectives different from their GS (Subcategory D1). In the case of the G1.D1, the fact that the group used a search from the RPEQ website different from the content they would address contributed to formulating new objectives. However, in its objectives, G1 emphasised the development of learning chemical concepts, while in its GS, the objectives were directed to the development of aspects that go beyond the conceptual content. Therefore, G1 aimed at learning conceptual content to the detriment of other types of content intended in its GS, such as attitudinal and procedural content. G5.D1, despite addressing the same content and theme as the GS, the teachers' adaptations consisted of detailing their objectives, contemplating not only the conceptual contents but also the procedural and attitudinal ones (Pozo & Crespo, 2009).

G2 and G4 presented objectives similar to GS (Subcategory D2) and made some adaptations, as they meant to work on the same contents as the studies of the RPEQ website. However, the objectives of the G2.D2 were more detailed regarding their learning intentions than the GS, specifying not only conceptual content but also procedural and attitudinal ones (Pozo & Crespo, 2009). The planning of G4.D2, though, was based on a GS developed at the higher level, so the teachers in this group adapted their objectives to their target audience, i.e., 1st-grade high school students. G3, in turn, was the only group that presented its objectives as the GS (Subcategory D3), therefore not performing any adjustment to the objectives.

About Category E concerning the *problem* proposition, we observed that G1, G4, and G5 proposed different problems from the GS based on the construction of new problems (Subcategory E1). G1.E1 and G4.E1 presented problems aimed solely at discussing chemical concepts based on examples with everyday situations and/or materials (Leite, Soares, & Barbosa, 2021). However, although G1 did not contextualise the problems in real thematic situations, they attempted to explain everyday situations involving different chemical reactions through an experimental activity before presenting the problem. G4, on the other hand, tried to contextualise it by displaying images of everyday matters to introduce problems involving chemical bonds.

These observations allowed us to infer that for G1 and G4 teachers, contextualising is just exemplifying everyday scenarios involving chemical concepts without, for example, an articulation between aspects of science (chemistry) and technology, society, and the environment, as suggested by Carvalho and Gil-Perez (2011). G5.E2, in turn, chose to build a problem and insert it in a contextualised situation, aiming to work on the three types of content, conceptual, procedural, and attitudinal, and also discuss aspects of science, technology, society, and the environment (Pozo & Crespo, 2009; Carvalho & Gil-Perez, 2011).

Only G3 adapted to the GS problem (Subcategory E2). The group's teachers presented an introductory text different from the GS to contextualise the problem. However, they addressed the same theme as indicated in Subcategory C2 and proposed a different questioning of the GS contemplating the context for which the planning was prepared (hinterlands of Paraíba) (G3.E2).

G2 was the only group that used the same GS problem (Subcategory E3). We believe that the problem of garbage is shared in a large part of Brazil. Therefore, G2 may have chosen to use the same problem as the GS because it is closer to the school context the group members had thought.

Regarding Category F, we aimed to analyse the dynamics of the activities proposed by the teachers to find out whether they had adapted the sequence of activities or would have organised their planning in the same sequence as the GS. We emphasise that the order presented in Table 3 (Appendix A) in Category F does not correspond to the number of classes stipulated in the planning of the groups but rather refers to the sequence proposed by the teachers. To exemplify, we explain that the experimental activity and the raising of hypotheses in G1 took place in the same class, but the experimental activity happened before the hypotheses. That said, we observed that no group proposed a sequence such as the GS (Subcategory F1), but, instead, chose to adapt the dynamics of the TS activities (Subcategory F2).

G1, for example, presented a sequence of activities different from the GS by proposing the performance of an experimental activity, raising the students' previous conceptions and presenting the problem after discussing the conceptual contents. Under this last direction, G5 also proposes discussing the chemical contents before presenting the problem situation and, at the same time, differs from the GS by suggesting a research activity.

However, according to Pozo (1998), the problem is a situation that the individual wants and must resolve, but that does not have a quick or immediate way to the solution. To solve the problem, teachers must use resources to guarantee students the means (instructions, materials, application of skills, abilities) that may be useful for carrying out the proposed task (problem) and enable the construction of knowledge (Meirieu, 1998). Conjecturing with these ideas, Leite and Afonso (2001) point out that the students must first receive the problem to investigate later, i.e., and then search for the solution through resources provided by the teacher, as explained by Meirieu. These assumptions, therefore, corroborate the methodological stages of the PS approach shown in Figure 1, especially regarding the moment of presenting the problem to the students in a TS based on this approach, being delivered to the student before the discussion of the concepts of the content that involve the problem situation.

Thus, the fact that the problem was presented after the theoretical explanation of the content, as was the case with G1 and G5, may not constitute a problem for the student, not causing, therefore, a cognitive conflict, as there is the possibility of the non-existence of an obstacle that is necessary to build learning. In this way, the "problem" can be solved quickly. Thus, we understand that for better success of the PS approach, they should propose the problem before approaching the conceptual type contents, as occurred in most of the works involving this theme for the teaching of chemistry (see the RPEQ website).

The dynamics of activities in G2 differ from their GS, as they propose to carry out a hypothesis survey on a possible solution to the problem, in addition to not presenting an experimental activity as the GS did. G3, on the other hand, made adjustments in the sequence of the GS regarding the proposition of raising hypotheses and the moment of proposing the problem to the students. Although G3's GS presented the problem situation after discussing the contents, the group proposed the problem before a dialogued expository class on chemical concepts, as suggested by the PS approach literature.

The sequence of activities in G4 differs from the GS, especially regarding the survey of previous conceptions proposed by the group, since the

GS did not carry out this activity. Also, the GS carried out a hypothesis survey, an experimental activity and took a moment to present the solution to the problem. However, we show that these situations were not contemplated by the G4, especially when presenting the solution to the problem situation, which the G4 did not clarify in their planning material and presentation.

The PS-approach literature explored in the methodological steps we have in Figure 1 suggests, as an essential moment in the implementation of this approach in the classroom, the teacher's and students' presentation of the answer(s) to the problem during the development of the TS.

For Category G, we sought to analyse the activities and resources pointed out by teachers in their TS to help students solve the proposed problem. We noticed that all groups suggested carrying out new activities and new didactic resources different from the GS (Subcategory G1)), even those who proposed tasks equal to the GS (Subcategory G2), as was the case with G2.G2, G4.G2, G5.G2. Besides, groups G1.G3, G3.G3, and G5.G3 made adjustments in the activities and resources of the GS, as exposed in Subcategory G3. Therefore, no group proposed all activities as they were carried out in the guiding research works (GS).

Thus, we could infer that the training activity on the PS approach contributed to teachers' thinking and organising activities and didactic resources beyond the exercises, the board, and the slides, considering their classroom contexts, to enable students' engagement during the teaching sequence and assist in problem solving. This result corroborates, therefore, the training need listed by Carvalho and Gil Perez (2011) concerning *Knowing how to prepare activities that generate fruitful learning*.

In addition, the RPEQ website can help teachers propose different resources and activities for chemistry classes, considering that the TS available present the use of games, simulations, hypermedia, comics, cartoons, films, etc. We also highlight the need to diversify teaching, whether or not it is anchored in PS, incorporating other types of tasks, such as those related to the SD: scientific dissemination texts, podcasts about science, FakeScience, and carrying out activities in non-formal teaching spaces such as field visits, theatre visits, museums, etc. Although these aspects of SD have been discussed in the training process, the teachers did not include these activities in their teaching sequences.

Analysing Subcategory G1, we can note that all groups proposed a moment for discussing chemical contents through an expository class dialogued similarly to the GS. From the perspective of the PS approach, the expository dialogued class is not configured as a teaching methodology but rather as one of the activities to be mediated by the teacher to help students solve the problem. Thus, when using PS, teachers should not necessarily abandon traditional teaching methods, but not make them hegemonic, as traditional teaching can also foster the construction of chemical knowledge (Carvalho & Gil-Pérez, 2011).

However, the teacher must carry out a critical analysis of traditional teaching, as highlighted by Carvalho and Gil-Perez (2011) to add to this method different activities, resources, and didactic approach, enabling students to learn more critically and reflectively about chemical science aiming to relate this science with their society. In this way, all groups proposed resources and activities in the TS, such as: using images (G2 and G4), videos (G1, G3, G4, and G5), experimental activity (G1, G3, and G5), team activities (G1, G2, G3, G4, and G5), seminar presentation (G2, G3, and G5), using infographic or conceptual maps (G2), comics (G2), research activity (G5), and class expository dialogue (G1, G2, G3, G4, and G5). The resources and activities most explained by the groups are team activities, videos, experimental activities, and seminars.

All groups proposed team activities and their GS. Carrying out activities in groups is essential in the PS approach, as they provide collaboration, social interaction, communication, and the exchange of ideas among students, favouring learning (Delman & Hoeberigs, 2009; Leite & Esteves, 2005; Souza & Dourado, 2015).

About experimentation, the PS approach certainly has a high potential for proposing investigative teaching (Silva, Sá, & Batinga, 2019), which has as its main foundation the performance of an experimental activity based on a problem situation (Campos & Sena, 2020). Thus, for students to solve the problem, they must investigate experimentally.

Regarding the videos, studies (Leite, 2015; Valença *et al.*, 2021) point out the use of videos as a relevant resource for mediating the teaching and learning process due to their dynamic, playful and informative character, which can make the class more attractive and provide student engagement. As for the Chemistry school topic, the videos also show the demonstration of experiments when the school does not have adequate space to carry out experimental activities or lacks materials and equipment. Groups G1 and G5 used the videos to achieve the first intention. G3 and G4, on the other hand, aimed at the second purpose.

Seminar activities have proven to be a very relevant activity within the PS approach (Souza & Dourado, 2015; Leite & Afonso, 2001), as teachers can use it as the final task of a TS for students to present their answers to the proposed problem situation to share and discuss the answer(s) of each group with the whole class. At the same time, teachers check whether the problem has been solved and whether the justifications for answers and non-answers are relevant.

The last category of analysis is Category H, referring to the teachers' suggestion to survey the students' previous conceptions. We emphasise that all groups proposed the survey on the students' previous conceptions, whether it be questions related to the theme or the chemical content, as explained in the previous section in the analysis of teaching purposes, even if the GS did not carry out this type of activity, as it was the case of the GSs of G1 and G4. G3 was the only group that adjusted the previous conceptions raised by the GS (Subcategory H2). The other groups presented questions different from the GS (Subcategory H1).

As Souza and Dourado (2015) indicated, identifying students' previous conceptions is an important activity of the PS approach to provide feedback to the teacher to guide their teaching planning. In this way, we believe that the teachers could understand the importance of surveying the students' initial conceptions to direct their actions in their planning and/or start raising hypotheses about the problem or other situations presented to the student in a TS based on the PS, as was explained during the presentation of some groups.

FINAL CONSIDERATIONS

By carrying out continuous training on the Pw approach and SD, we make it possible to discuss with the teachers the training needs, as indicated by Carvalho and Gil-Perez (2011), resulting in the construction of plans and the proposition of activities that contribute to learning chemical knowledge more effectively.

After analysing the theoretical-methodological adaptations of the teachers' PS, we noticed that they used few elements as presented in the GS in their teaching plans. Therefore, they built different plans according to the typical classroom context chosen by the group members, demonstrating autonomy and creativity. They made adjustments by proposing new situations or changes/adaptations in content, objectives, problem, resources, and activities, among others. The teachers also proposed adaptations to the PS approach regarding the teaching modality, adapting the research of the RPEQ website for remote teaching.

From this perspective, we could observe the potential of the RPEQ website concerning its functionality as a digital didactic resource, as presented by Freitas and Campos (2018). In this way, the website served as a basis for teachers to plan teaching situations different from traditional methods, providing them with a direction to build their problems and their TS.

However, we also found weaknesses in teachers' planning regarding some theoretical-methodological foundations of the PS approach, such as the construction of problems focused only on the discussion of conceptual content (Pozo & Crespo, 2009); the lack of contextualisation of the problem limited only to the process of example; the proposition of the problem after approaching the chemical concepts; the lack of explanation for a moment to present the solution to the problem; and teachers' poor exploration of the TS assessment process.

These frailnesses may have occurred due to the pandemic context faced by all and, in more severe cases, the experience of the illness caused by covid-19 and the loss of loved ones; due to the remote format and the number of meetings held in the formative activity, which were not enough to explore and monitor the groups more closely in the preparation of their plans.

Finally, aiming to overcome the weaknesses found in this study, we suggest the following actions be developed in the initial and continuing education courses for chemistry teachers, in addition to suggestions for future research in chemistry teaching. They are, emphasising the theoretical-methodological aspects of PS found to be frail, developing activities involving the SD of research in the context of chemistry teaching, promoting discussions in the training processes of chemistry teachers about the assumptions of contextualisation, the relationship of chemical content with aspects of science, technology, and society and also with the history and philosophy of science, associating these themes with the PS approach whenever possible since the latter was not addressed in the teachers' planning.

AUTHORSHIP CONTRIBUTION STATEMENT

APF and AFC conceived the presented idea and actively participated in data collection. APF analysed the data, and AFC guided the discussion and contributed to the writing of the text.

DATA AVAILABILITY STATEMENT

The data supporting the analysis of this research will be made available by the correspondent, APF, upon reasonable request.

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APPENDIX A

Table 3

Sample Analysis of the categories referring to the theoretical-methodological adaptations of the problem-solving approach carried out by the teachers in their planning

Category A - Teaching mode				
Subcategories	**Registry units**	**Context units**		**Code***
A1. Classroom teaching	Use of the physical space of the classroom, development of activities with physical materials/objects and school labs.	G1: "At the end of each video, the teacher could make a theoretical explanation, write on the board [at school], equalise".		G1. A1 G3.A1 G4.A1 G5.A1
A2. Adaptation for remote teaching	Use of online spaces.	G2: Use of Google Meet and Google Classroom as a class space.		G2. A2
Category B – Content				
Subcategories	**Registry units**	**Context units (Teachers' TS** content)**	**Context units (Content of the GS***)**	**Code**
B1. New Content	The teachers addressed a content different from the GS.	G1: Chemical reactions and equations	GSG1: Chemical Element/ Simple Substance/Composed Substance/Mixtures	G1. B1
B2. Same Content	The teachers addressed a content equal to the GS.	G2: Chemical Reactions/ Physical and Chemical Processes/ Mixture Separation.	GSG2: Chemical Reactions/ Physical and Chemical Processes/ Mixture Separation.	G2. B2 G3.B2 G4.B2 G5.B2
B3. Insertion of content	The teachers inserted a content in	G4: Ionic, Covalent and Metallic Bonds	GSG4: Ionic and Metallic Bonds	G4.B3

	relation to that of the GS.			

Category C - Theme				
Subcategories	**Registry units**	**Context units (Teachers' TS theme)**	**Context units (GS Theme)**	**Code**
C1. New theme	The teachers proposed to discuss a different theme from the GS.	No group	----	---
C2. Same theme	The teachers proposed to discuss the same theme as in the GS.	G2: Garbage G3: Biodiesel G5: Food preservation	GSG2: Garbage GSG3: Biodiesel GSG5: Food preservation	G2. C2 G3.C2 G5.C2
C3. No thematic	The teachers did not propose the discussion of a topic.	G1: There was none.	GSG1: Agriculture	G1. C3 G4.C3

Category D – Objectives				
Subcategories	**Registry units**	**Context units (Objectives of teachers' TS)**	**Context units (Objectives of the GS)**	**Code**
D1. New objectives	The groups set objectives different from those who were pointed out in the GS.	G1: "Identify chemical reactions that happen in everyday life".	GSG1: "Address the mixing concepts, simple substance, compound substance, and chemical element, relating them to a theme of social significance and linked to students' context in a given school".	G1. D1 G5.D1

D2. Adapted objectives	The teachers proposed objectives similar to the GS performing change/ adaptations.	G2: - "Understanding the importance of using resources in a sustainable way". - "Knowing the difference between forms of waste treatment". - Meet the proper functioning and treatment of waste disposal."	GSG2: "To develop knowledge relating to the problem of garbage and at the same time sensitise them on the various issues associated with waste, such as types of garbage, excess of consumption of products industrialised, recycling and selective collection, different forms of waste treatment, among others".	G2. D2 G4.D2
D3. Identical objectives	The teachers proposed objectives equal to the GS.	G3: "Recognise and characterise biodiesel according to its physical and chemical properties".	GSG3: "Recognise and characterise biodiesel according to its physical and chemical properties".	G3.D3
Category E - Problem				
Subcategories	**Registry units**	**Context units (Teachers' TS problem)**	**Context units (GS Problems)**	**Code**

E1 . New problem	The teachers built a problem different from the GS.	G1: “Is there any kind of transformation in food during cooking? If yes, is there formation of new substances? If yes, choose a food and describe the transformations that occurred in its cooking process. For this, use the language and representation of chemical knowledge? [...]”.	GSG1: “A farmer who owns a small property with sandy soil [...] used to grow a bean monoculture for long periods. After a few years, he observed that his production was decreasing with each harvest. To return to produce as much as before, the soil must be fertilised, but how to determine the necessary amount and which is the best type of fertiliser for this crop?”.	G1. E1 G4.E1 G5.E1
E2. Adapted problem	The teachers proposed problems similar to the GS performing changes/adjustments.	G3: “Last Thursday, the ANP resumed the biodiesel auction, reversing the decision of the Federal Court of Rio de Janeiro, which complied with the request of the Association of Biodiesel Producers of Brazil (Aprobio). Producers claim that, with the increase in soy exports, used as raw material in the production of fuel, the cost of manufacturing has risen and the auction reference price is not	GSG3: “[...] The plane, called the BioJet I, crossed the United States from coast to coast. The initiative was organised by Green Flight International, founded in 2006, to promote and encourage the use of fuels that do not harm the environment in aviation [...]. Based on the properties and characteristics of biodiesel, explain	G3.E2

		enough to adequately remunerate production [...]. Based on the properties and characteristics of biodiesel, explain why it can be a better fuel alternative than the current ones? Explain why biodiesel production can be an alternative for the socioeconomic development of the sertão ”.	why it can be a better fuel alternative than the current ones? [...] According to the test carried out, specialists defend the reliability of biodiesel, but as a futuristic proposal. Why?”.	
E3. Identical problem	Teachers proposed objectives equal to the GS.	G2: “The mayor of a city in hinterland Pernambuco noted that in recent years there has been a growing production of garbage caused by the residents of his city [...]. For the mayor to put an end this complex social issue, this population must be correctly made aware of the situation and control local waste production, but how to guide the population to change their attitudes and what are the possible ways of treating waste?”	GSG2: “The mayor of a city in Pernambuco hinterland noted that, in recent years, the city’s population increased their garbage production [...]. For the mayor to be able to put an end to this complex social issue, it is necessary to raise awareness of this population and control the production of local waste, but how to guide the population to change their	G2. E3

			attitudes and what are the possible ways of treating waste?”	
Category F - Activity dynamics				
Subcategories	**Registry units**	**Context units (Dynamics of teachers’ TS activities)**	**Context units (Dynamics of GS activities)**	**Code**
F1. Sequence of identical activities	The teachers proposed a sequence of activities equal to the GS.	No group	----	---
F2. Adaptation of the sequence of activities	The teachers performed changes in the sequence of activities carried out in the GS.	G1: 1st Conducting an experimental class. 2° Surveying hypotheses about the situations of the experiment. 3rd Surveying previous conceptions. 4th Explaining theoretically the content through different activities. 5th Presenting and discussing the problem. 6th Problem resolution.	GSG1: 1st Presenting the problem. 2nd Raising hypotheses. 3rd Explaining theoretically through different activities. 4th Problem resolution.	G1. F2 G2. F2 G3.F2 G4.F2 G5.F2
Category G - Resources and activities				
Subcategories	**Registry units**	**Context units (Teachers’ TS resources and activities)**	**Context units (GS resources and activities)**	**Code**

G1. New resources and activities	The teachers proposed activities different from the GS.	G5: - Experimental activity - Research activity - Conversational expository class - Video exhibition - Seminar presentation - Formation of groups	GSG5: - Picture presentation - Conversational expository class - Experimental activity - Group formation	G1. G1 G2. G1 G3.G1 G4.G1 G5.G1
G2. Identical activities	The teachers proposed activities equal to those of the GS.	G5: - Dialogued expository class on the concept of chemical kinetics.	GSG5: - Dialogued expository class on the concept of chemical kinetics.	G2. G2 G4.G2 G5.G2
G3. Adaptations of resources and activities	The teachers proposed changes in the activities and resources carried out by the GS.	G1: - Dialogued expository class [with video help].	GSG1: - Dialogued lecture [with molecular structure construction aid].	G1. G3 G3.G3 G5.G3

Category H - Survey of previous conceptions

Subcategories	**Registry units**	**Context units (Teachers' TS questions)**	**Context units (GS questions)**	**Code**
H1. New questions	The teachers proposed questions of previous conceptions different from the GS.	G4: "In the world, there are several different chemical substances, can you explain how they form? [...] Have you ever heard of chemical bonds, yes or no? If so, what do you understand by chemical bond?"	GSG4: There was not survey of previous conceptions	G1. H1 G2. H1 G4.H1 G5.H1

H2. Adaptation in questions	The teachers proposed changes in the questionnaire of previous conceptions of the GS.	G3: "Do you know biodiesel? How did you find out about this fuel? Justify your answer. What raw materials can be used in the production of biodiesel? How is biodiesel produced? What is the importance of using biodiesel?"	GSG3: "Do you know biodiesel? How did you find out about this fuel? Justify your answer [...]. According to the current reserve of oil, with the discovery of the pre-salt, do you consider investment in research into other fuels necessary for the Brazilian energy matrix? Justify your answer".	G3.H2
H3. Identical questions	The teachers proposed questions about previous conceptions equal to those of the GS.	No group.	-----	---

Note. * Code = Analysis Code **TS = Teaching Sequences ***GS = Guiding Studies