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PROBLEMATIZED EXPERIMENTAL ACTIVITY (PEA): A SYSTEMATIZATION PROPOSAL FOR EXPERIMENTAL TEACHING OF CHEMISTRY

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Abstract: This article presents and discusses a systematization strategy aimed at the experimental teaching of science, here in the particularities of teaching Chemistry, characterized as a Problematized Experimental Activity (AEP), of a theoretical-methodological nature, in which theoretical and methodological articulating axes appear. methodological moments. The objective is to characterize a potentially problematic teaching proposal with regard to its conduction, as well as the reflections it raises, based on experimental practice, capable of promoting the production of scientific knowledge demarcated by the effective understanding of its structuring aspects, supporting it. whether in/by the procedural nature of the theory-practice relationship.
Keywords: Experimentation, Teaching/ learning of Chemistry, teaching methodology.

INTRODUCTION

The specific literature has, in recent decades, dedicated itself to the study, reflection and systematization of the theoretical and methodological aspects present in the teaching and learning activities of Science, as well as in their pedagogical systemic derivatives (CACHAPUZ, 2005; GIL-PERES, 1993; GIL; CASTRO, 1996; GALIAZZI; GONÇALVES, 2004; PERRENOUD, 2000). In this perspective, experimentation is conceived as capable of contributing to such processes, under perspectives that conceive the teacher-student relationship as one that must favor training rather than information.

Based on a theoretical research of a qualitative nature, this article presents and argues about the Problematized Experimental Activity (AEP), a proposal for a theoretical-methodological systematization aimed at the experimental teaching of Science, originally materialized by the publication of two works in which, in the first, Silva and Nogara (2018) present examples of AEPs in the context of teaching Chemistry and, in the second, Silva and Moura (2018) extend it to other Sciences, basing it pedagogically-epistemologically. Also, since 2015, articles have been on the subject (SILVA; MOURA; DEL PINO, 2015; 2017; 2018; SILVA; FERREIRA; PEREIRA; FILHO, 2019; MOREIRA; SILVA; MOURA; DEL PINO, 2019).

PROBLEMATIZED EXPERIMENTAL ACTIVITY (AEP): A PROBLEM-EXPERIMENT PROCEDURAL RELATIONSHIP

A PEA is configured as a teaching-learning process, in the particularities of experimental Sciences, which develops from the demarcation of a problem of a theoretical nature, that is, as a practice that aims at the search for an acceptable solution to a given situation -problem. By acceptable solution, it is understood the construction of a network of concepts interconnected in a consistent way that, through the experimental way of referential character, acquires the status of verisimilitude or approximate truth.

Based on this concept, an AEP aims to develop students' autonomy by making records, discussing results, raising hypotheses, evaluating possible explanations and discussing, with their peers and the teacher, methods, justifications and limits circumscribed to the experiment. In doing so, AEP creates, in the context of a classroom, an investigative community that reproduces, with particularities related to the pedagogical nature of the approach, the social dimension of scientific work.

Guridi and Islas (2008) cite some criteria that must be prioritized when preparing a practical activity capable of generating meanings and understandings. They are: awakening students' motivation; identify and consider previous ideas about the

phenomenon to be studied and that allow students to formulate their own hypotheses; develop different forms of experimentation; stimulate discussion between the working groups; propose experiences that emphasize qualitative and not only quantitative aspects; introduce, as far as possible, the History of Science, to enable the student to know the problems that permeate a given scientific community in a given period and the way in which they were approached.

This process is complemented with oriented discussions after the experimental activity, which provide conditions for exchanging ideas and deepening arguments, an essential process for the student to appropriate the theme from the development of the ability to reconstruct the semantics of the experiment, and the consequent interpretation of the phenomenon, based on his own words.

Mortimer; Machado and Romanelli (2000) state that practical activities carried out in an exempt – or disjointed – way from moments of theoretical-practical discussion are, in most cases, insufficient in terms of their purposes. On the other hand, an experimental activity structured in AEP can qualify the teaching-learning processes, becoming a respectable pedagogical strategy for scientific approaches, in a science laboratory, didactic, in the classroom or in another formal environment.

THEORETICAL-METHODOLOGICAL STRUCTURE ORGANIZING AND TRIGGING THE AEP

By understanding the indispensability of a theoretical-methodological foundation for any teaching intervention with learning purposes, it is proposed as and is called Problematized Experimental Activity (AEP) a didactic-pedagogical strategy for the experimental teaching of Science, configured in two main axes, one theoretical and the other methodological, associative and potentially inseparable. In summary, Chart 1 shows its denotative foundations, treated as theoretical (and their articulators) and methodological (and their moments) axes.

Axes	
THOERY	**METHODOLOGICAL**
A. problem proposition B. experimental purpose C. Methodological guidelines	i. prior discussion ii. organization/ development iii. Return to the working group iv. Socialization v. Systematization

Chart 1. AEP's denotative elements: theoretical and methodological.

Source: Silva e Moura (2018).

THEORETICAL AXIS: AEP ARTICULATORS PROPOSED PROBLEM

It is considered as the theoretical axis of the PEA, in its articulating elements, a configuration that is structured from the demarcation, elucidation and proposition of a problem of a theoretical nature, that is, a PEA conforms theoretically as a search strategy for a solution the given problem situation.

From then on, an experimental objective is elaborated, dealing, from a broad perspective, with what is expected to be empirically developed in terms of experimental product/ action, and methodological guidelines, guidelines for actions that will potentially result in the aforementioned experimental product/ action of interest. Therefore, the experimental teaching proposal coined as AEP proposes an articulation between experimental objective and methodological guidelines, based on the proposition and critical analysis of a problem, for which a possibility of solution will be sought, in this particular case, through the methodological use of experimentation.

This texture, represented in Figure 1, is embodied in the Epistemology of Thomas

Kuhn (ETK), in view of its theoretical aspects that defend a non-deterministic scientific knowledge, socially constructed and favored by a theory-experiment adaptation and by an empirical protocol, demarcated here as an experimental planning guide (KUHN, 1998; 2000).

With reference to the articulating elements, components of the theoretical axis of the AEP, in a succinct way, the planning of the activity is established by proposing a problem, of a theoretical nature, articulated to content units of interest. This problem requires, for its development, an experimental objective, from which propositions guiding actions, called methodological guidelines, will be derived. In the case of reliable "compliance" by the students with these instructions, the said objective will be answered, but not the problem, for which a deeper understanding of the actions undertaken and their derived results will be required.

The elaboration, presentation and elucidation of these axes are configured in the attributions of the professor, proposer and organizer of the experimental activity, laboratory or deliberated by him in another space. In detailed aspects, it will move on to a specific discussion of the characterization of the problem, objective and guidelines, essential theoretical elements for the planning and systematization of an AEP.

PROPOSED PROBLEM

In the search for a "[...] conceptually sophisticated and socially productive educational planning" (EICHLER; DEL PINO, 1996, p. 12), it is suggested the elaboration/identification/adaptation of a problem (a problem-situation), capable of triggering a potentially significant pedagogical intervention, resulting in psychological learning. In the demarcation of AEP itself, this problem must encompass a theoretical nature, preferably contextualized, linked to content units of interest. For its solution, it encourages the search for a route of experimental actions adaptive to different realities, which will lead to data that, after being transformed – collected, systematized, analyzed, understood and communicated – may lead to a solution perspective, qualitative and/or quantitative.

It is not proposed here the sole acceptance of expected solutions, nor the refusal of those not considered, but the permissiveness of the subjects in defending their points of view in the face of what they consider adequate to solve the proposed problem. In particular, Freire (1997, p. 82-83) advocates in this regard by signaling that "[...] in its process, problematization is the reflection that someone exercises on a content, the result of an act, or on the act itself, to act better, with others in reality". Based on this problem, an experimental objective is elaborated, according to the AEP theoretical articulator.

EXPERIMENTAL OBJECTIVE

Refers to proposals for practical activities that operationalize experimentation. Which technique is essential for generating data, which will be underlyingly transformed into results and, with that, will offer potential practical subsidies to the solution of the proposed problem? At the end of the empirical procedures, what do you intend to obtain/produce? What product/object can be generated? Therefore, it intends to lead the subjects to the generation of results, but not necessarily to the solution to the proposed problem, since these must be analyzed and understood significantly for that purpose, provided that the problem is opportune and congruent to this end.

In summary, the experimental objective is configured as the final experimental axis that will guide the main action to be developed, that is, as a technique which will

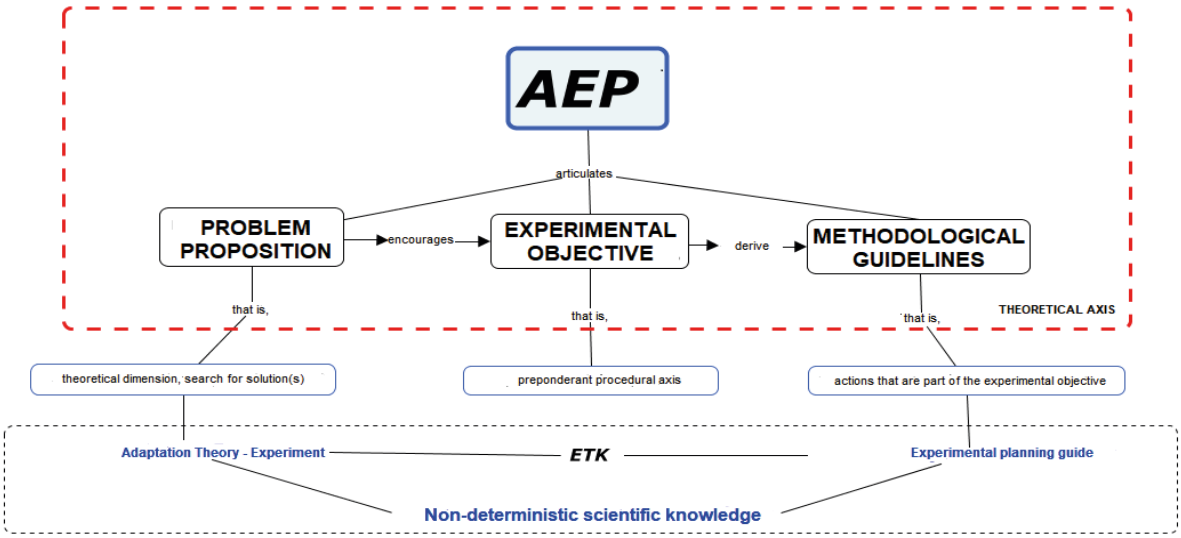

Figure 1. Theoretical articulators for the AEP proposal; epistemological subsidies. Source: Silva and Moura (2018).

	Chemistry teaching
Proposed problem	The identification of acidic and basic substances can be done by means of universal indicators, as is the case, for example, of phenolphthalein, which is colorless in an acidic medium and pink in a basic medium. However, we can use everyday substances for the same purpose, such as tea samples, some species of flowers and red cabbage. This being the case, what must be the color of a lemonade when treated with a few milliliters of an alcoholic solution of red cabbage?
Experimental purpose	Produce acid-base indicators and test different indicators in acid and base solutions.
Methodological guidelines	(i) Separately, crush some rose petals and red cabbage leaves in a mortar. (ii) Add a few milliliters of alcohol to the systems and filter. (iii) Store the indicators in appropriate bottles. (iv) Hot extract the pigments from the tea samples in an aqueous medium and store them. (v) Thus, three natural indicators will be formed. (vi) Arrange, in a grid, six test tubes in one line and six test tubes in another, identifying them [...].

Table 2. Exemplification of AEP in Chemistry teaching.

Source: Silva and Nogara (2017).

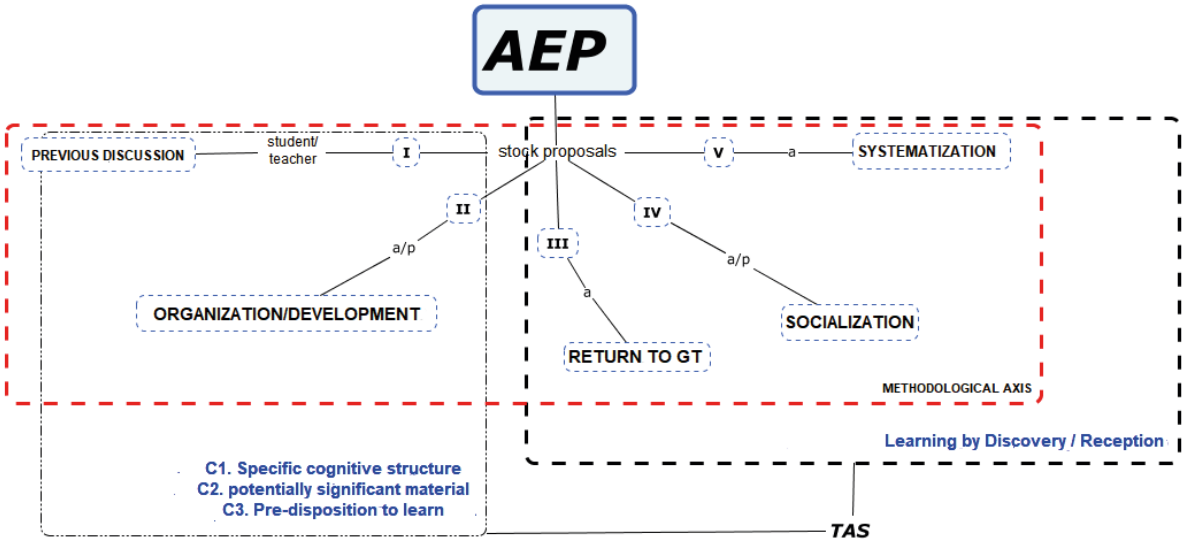

Figure 2. Methodological moments for the AEP proposal; pedagogical subsidies. Source: Silva and Moura (2018).

require actions capable of concretizing it; of detailed proposals. It derives, therefore, in methodological guidelines.

METHODOLOGICAL GUIDELINES

Not under a prescriptive tendency, but reinforcing the idea of procedural orientation, the methodological guidelines consist of a protocol of practical actions derived from the experimental objective. They act as guiding proposals for the procedures to be carried out. They must not be accepted as a limiting factor for experimentation; it is argued here that learning is reduced when dealing with experimentation under observational or deterministic procedural biases, pointed out in the specialized literature as a "cake recipe".

However, such indications appear as a necessary step, which offers the establishment of the first actions and guides the general actions. They are not reduced to impositions, and can be changed/adapted at any time by the teacher and/or students, given the real conditions.

As an example, Chart 2 shows an AEP on the particularities of teaching Chemistry, which was elaborated from the treated fundamentals, considering the proposed problem, experimental objective and methodological guidelines, theoretical-methodological elements that legitimize it.

As it can be seen, different methodologies may lead to different solutions, even if the same heuristic is adopted, which is healthy and desirable for the purposes of AEP. It is hoped, therefore, that this configuration can be extended to the requirements of other areas of Science, since it focuses on experimental teaching with learning purposes, by bringing the procedural technique closer to problem solving.

AEP'S METHODOLOGICAL AXIS

It is proposed to outline the AEP through a methodological sequence consisting of five steps, characterized as moments. It begins with an introductory discussion involving teacher and students; it is consolidated by the materialization of a product, developed by these students. Such moments, however, are dynamic and may be adapted to the specific purposes and purposeful characterizations of the subjects involved, with their critical analysis starting from the planning of the activity, encouraging a continuous proposition of derivative actions.

This methodological protocol, represented in Figure 2, is articulated with the Theory of Meaningful Learning (TAS), in view of certain concepts/principles originating from it, such as the three imperatives for learning characterized as meaningful: specific cognitive structure, potentially significant material and pre-disposition to learn, and distinct modes of learning germination: by discovery and by reception (AUSUBEL, 2003). An adequate survey of prior knowledge, which Ausubel calls subsumers, which can guarantee that experimental practice is in the students' zone of proximal development, is also important.

The following actions are considered, in their systematization, as a pedagogical strategy consistent with their purposes of theoretical and methodological structure to a learning capable of generating meanings, not in a rigid format, but encouraging a permissive teaching of reconfiguration of knowledge and reconstruction of meanings by its integrating subjects. It is also worth confirming the relevance of involving teachers and students in each of these actions, based on convincing the teacher with regard to the most favorable theoretical and methodological circumstances imbued, in view of their pedagogical profile, their epistemological conception and the means and resources available.

There are, therefore, five moments: (i) previous discussion, (ii) organization/ development of the experimental activity, (iii) return to the work group, (iv) socialization and (v) systematization, presumed as essential to a teaching activity that offers methodological subsidies to the theoretical aspects of AEP.

PREVIOUS DISCUSSION

As a triggering action of the AEP process, an introductory discussion is proposed, in the classroom or laboratory, as a proposal to identify the students' prior knowledge about the main themes to be addressed. It can take place through a theoretical discussion, with dialogue exposure of specific topics to the techniques and their fundamentals proposed experimentally, operationalized by the use of printed materials, such as texts, contextual and concrete situations, questions, open questionnaires, or another instrument that proves to be adequate. The central objective of that moment, in line with the TAS in its conceptualizations for subsumers and previous knowledge, consists of presenting, identifying and developing knowledge with the co-participation of students (AUSUBEL, 2003, 1978).

In summary, the aim is to investigate students' initial knowledge of previously consolidated scientific content and their relationships based on these characterizations and, underlyingly, to introduce and develop theoretical scientific foundations capable of guiding the next stages of the process. The disciplinary knowledge that underlies experimentation must emerge at this stage, which involves, in its preparation, development and evaluation, students and teachers.

ORGANIZATION/DEVELOPMENT OF THE EXPERIMENTAL ACTIVITY

This step, in general, aims at the procedural organization of experimentation. It begins by proposing the theoretical problem (elaborated, identified or selected) and its derivations into an experimental objective and methodological guidelines. It advances to the collective implementation of an organization of experimental work, involving the placement of students in small groups, with subsequent recommendation for initial discussions in each group, followed by the raising of hypotheses that contribute to the solution to the proposed problem, emerging from the students' prior knowledge.

Then, the development of the experimental activity takes place, in which the students carry out the experimentation based on their own interpretation of the AEP, with the purpose of "[...] theorizing the practice and practicing the theory" (PIMENTA, 2011, p. 259). In this space, they record information and direct observations in the logbook, through descriptions, images, tables, graphs, or any other relevant resource. According to Zabala (1998, p. 99), it is inferred that "[...] they will have to see, touch, experience, observe, manipulate, exemplify, compare, etc., and from these actions it will be possible to activate the mental processes that allow them to establish the necessary relationships for the attribution of meaning". This phase involves, in its elaboration, development and evaluation, students and teachers.

RETURN TO WORKING GROUP

The third proposed moment is intended to encourage reflection and discussion within the work groups, followed by the arrangement and systematization of the recorded information. After carrying out the experimental activity, students are asked to

return to their workgroup to sort the records they deem relevant. In this phase, they move on to the cognitive development that guides an understanding of the experimental data obtained, to be transformed into emerging results of a dialogic joint interpretation with perspectives of solution to the problem proposed at the beginning of the activity.

It is argued, in the context of AEP, that an experiment must extend beyond the simplicity of manipulations and records, as psychological understandings are generated by the applicability that subjects perceive to the empirical data obtained, in view of the meanings they develop about them. Upon returning to their peers, at the end of the practical activities, they become passive in the development of data/information processing capable of leading them to a solution to the original problem of the activities, generating collective conviction, due to the argumentative logic that it may present. This stage of the process essentially involves the students in its elaboration and development. Teachers, in their assessment, must approach each group, maintaining a neutral position, analyzing, in loco, resulting knowledge/doings.

SOCIALIZATION

Bearing in mind the prevalence of a procedural teaching-learning relationship, which undervalues the ends, the final products obtained, but encourages the constant search for solutions and for new questions that arise throughout the process, the moment of socialization gains relevance, as it "will demonstrate " the methodological paths followed from the justifications that each group will use when defending their results and a possible solution to the triggering problem of AEP. From the comparison between different points of view, a possible generalization can be made, bearing in mind the referrals given by the teacher.

Therefore, the moment in which socialization aims to encourage dialogue between the different work groups, bearing in mind theoretical-methodological distinctions that may lead to considerably different results and conclusions, consists of offering a collective space for the exchange of ideas regarding the procedures performed during the technique; conceptions of experimental successes and errors and perspectives of self-conviction followed by the elaboration of a qualified theoretical explanation to offer a collective solution to the proposed problem. Such an action is very relevant to the dimension of critical thinking, which has self-correction through argumentation as one of its main characteristics.

SYSTEMATIZATION

It is proposed the elaboration of a product as an essential action for learning and generation of own, particular, psychological knowledge. This strategy allows the systematization and recording of the perceptions generated in their possible derivation of an acceptable solution to the proposed problem. Guiding questions and/or protocol sections can be used to promote systematization and the application of conclusions to other realities. These perspectives of articulation with other contexts/objects of application must be overvalued, given that learning is characterized not exactly by the knowledge resulting from it, but by the ability of the learner to bring this knowledge to their practice, in view of their competence of action (ZABALA, 1998).

Normally, after the development of an experimental technique, the production of a report is requested, delivered by the work group. This strategy can be maintained, as long as guidelines are offered for its implementation, not in a rigid standardization - since its function is not professional, but pedagogical - but in order to offer students

subsidies as to a coherent way in which they can present their results and structure the products of their observations (SILVA; MOURA, 2018), a constitutive characteristic of scientific communication, in its requirement for reproducibility.

FINAL CONSIDERATIONS

This article presents and discusses the characterization of an experimental teaching strategy focused on the Sciences, entitled Problematized Experimental Activity (AEP), based on its own theoretical and methodological organizational structure. Bearing in mind that the practice of science teachers is inferred and nourished by their pedagogical and scientific conceptions, pedagogical and epistemological contributions underlying the planning, development and evaluation of the AEP experimental proposal were discussed. In this context, the Theory of Meaningful Learning and Thomas Kuhn's Epistemology were defended as consistent with what is proposed: an experimental science teaching capable of generating meanings and contributing to the production of scientific knowledge with effective understanding of its structuring aspects, extensible to its contextual and social dimensions, overcoming informative and prescriptive tendencies.

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