Obutchénie
Revista de Didática e Psicologia Pedagógica

DOI: http://doi.org/10.14393/OBv10.e2026-06

Diagnosis of the theoretical-systemic thinking of pre-service Chemistry teachers in Developmental Didactics: Contributions from the School of P. Ya. Galperin[1]

Diagnóstico do pensamento teórico-sistêmico de licenciandos em Química na Didática Desenvolvimental: contribuições da Escola de P. Ya. Galperin

Luiz Fernando Pereira[2]
Isauro Beltrán Núñez[3]

ABSTRACT
In Developmental Didactics, based on the contributions of P. Ya. Galperin and his school, the importance of teachers' theoretical-systemic thinking is emphasized in solving problem situations that require the elaboration of an orientation as a structural element of the intellectual activity of professional teaching thinking, which is essential for the formation and development of scientific thinking among basic education students in Chemistry classes. This study aimed to characterize the levels of theoretical-systemic thinking of Chemistry preservice teachers when justifying the occurrence or non-occurrence of chemical reactions. To this end, a study was conducted based on the methodology for characterizing professional teaching thinking developed by Núñez, Ramalho, and Pereira (2024), grounded in Galperin's (2023) studies on the formation of intellectual actions and concepts. As a data collection instrument, a pedagogical test composed of two questions was used. The results of the analysis indicate that, although the preservice teachers understand the meaning of the parameters of a chemical

RESUMO
Na Didática Desenvolvimental, com base nas contribuições de P. Ya. Galperin e de sua escola, destaca-se a importância do pensamento teórico-sistêmico dos professores na resolução de situações-problema que exigem a elaboração de uma orientação como elemento estrutural da atividade intelectual do pensamento profissional docente, essencial à formação e ao desenvolvimento do pensamento científico dos estudantes da educação básica nas aulas de Química. Neste trabalho, objetivou-se caracterizar os níveis de pensamento teórico-sistêmico de licenciandos em Química ao justificarem a ocorrência ou não de reações químicas. Para esse fim, realizou-se uma pesquisa baseada na metodologia de caracterização do pensamento profissional docente, desenvolvida por Núñez, Ramalho e Pereira (2024), fundamentada nos estudos de Galperin (2023) sobre a formação das ações intelectuais e dos conceitos. Como instrumento de coleta de dados, utilizou-se uma prova pedagógica composta por duas questões. Os resultados da análise indicam que, embora os licenciandos compreendam o significado dos parâmetros de uma reação química quando

---

[1] English version by Luiz Fernando Pereira. E-mail: luizfernandoifrn@hotmail.com.

[2] PhD in Science and Mathematics Education from the Graduate Program in Science and Mathematics Education of the Federal University of Rio Grande do Norte (PPGECM-UFRN). Orcid: https://orcid.org/0000-0003-2247-3717. E-mail: luizfernandoifrn@hotmail.com.

[3] PhD in Pedagogical Sciences from the University of Havana. Full Professor at the Center for Education of the Federal University of Rio Grande do Norte (UFRN). Orcid: https://orcid.org/0000-0003-3224-4694. E-mail: isaurobeltran@yahoo.com.br.

reaction when interpreted separately, they experience difficulties in integrating them and in systematically justifying the occurrence of reactions under certain conditions. These results suggest low levels of theoretical-systemic thinking among the research participants regarding the justification of the occurrence or non-occurrence of chemical reactions, highlighting the importance of considering the development of theoretical-systemic thinking as an object of intentional and conscious formation within the process of teacher education and professionalization, especially in educational perspectives aimed at enhancing teachers' intellectual development.

Keywords: Theoretical-Systemic Thinking. Systemic Approach. Diagnosis. Chemical Reactions. Developmental Didactics

interpretados separadamente, apresentam dificuldades em integrá-los e em justificar, de forma sistêmica, a ocorrência de reações em determinadas condições. Tais resultados sugerem baixos níveis de pensamento teórico-sistêmico entre os participantes da pesquisa no que se refere à justificativa da ocorrência ou não de reações químicas, o que evidencia a importância de considerar o desenvolvimento do pensamento teórico-sistêmico como objeto de formação intencional e consciente no processo de formação e profissionalização docente, especialmente em perspectivas formativas voltadas à potencialização da formação intelectual dos professores.

Palavras-chave: Pensamento Teórico-Sistêmico. Enfoque Sistêmico. Diagnóstico. Reações Químicas. Didática Desenvolvimental.

1 Introduction

Many studies in the field of Chemistry Education, within the school context, have emphasized that systems thinking constitutes a form of theoretical thinking of great relevance, which should be developed for the understanding of Chemistry contents from a holistic and integrative perspective, consistent with the nature of the object of study of this science (Hrin *et al.*, 2016; Núñez; Silva, 2019; Pereira, 2024).

This type of thinking makes it possible to explain the behavior of substances and materials in terms of their complex and systemic structure, which requires the mobilization of conceptual thinking of a theoretical-systemic nature. Nevertheless, several studies have identified, as argued by Hrin *et al.* (2016) and Pereira (2024), a limited understanding among students and teachers regarding complex systems and the mastery of theoretical-systemic conceptual thinking in Chemistry classes at different educational levels.

Several problems related to Chemistry learning in Secondary Education, such as the excess and fragmentation of contents, conceptual formalism that favors memorization processes, and the lack of a view of the complexity of chemical processes, among others, may be addressed and overcome, according to Mahaffy *et al.* (2018), through approaches that promote the development of students' theoretical-systemic thinking. In this regard, the authors emphasize that the reorientation of Chemistry teaching through this type of thinking may benefit students' learning and broaden the impact of Chemistry as a science in favor of society, further strengthening its already considerable capacity to contribute to the solution of global problems and to the promotion of the planet's sustainable development.

In the Theoretical School of P. Ya. Galperin, the issue of learning that fosters students' cultural (psychological) development constitutes a structuring idea for the development of theoretical-systemic thinking, which led to the configuration of the Galperin-Talízina System as a perspective within Developmental Didactics. According to Núñez, Pereira, and Barros (2024), this system is not limited to N. F. Talízina and P. Ya. Galperin, but encompasses an entire school of thought, including the contributions of L. F. Obukhova, Z. A. Reshetova, N. G. Sálmina, A. I. Podolskiy, V. V. Davydov, N. N. Nechaev, and A. N. Zhdan, among others.

According to Reshetova (2017), developmental teaching presupposes the restructuring of students' learning activity, its management, and the formation of new motives, objectives, means, and methods. Within this perspective, the formation of a new method of intellectual activity for the learning of cultural objects, designed within the instructional system, should be promoted as a condition for the development of students' conscious, creative, and harmonious personality.

When studying the relationships between teaching and students' intellectual development within the school context, Galperin (2023) established types of instruction related to the nature and characteristics of the orienting basis of action (OBA), and several studies, such as those by Talízina (1993) and Reshetova (1987), have shown type III OBA to be the most appropriate due to the student's independent mode of acquisition, its high degree of generalization, that is, its applicability to a broad family of problem situations, and its completeness in relation to the content. For Talízina (1993), the third type of OBA is of great interest to researchers insofar as it enables teachers to understand the psychologically significant nature of the relationship between learning and students' intellectual development, as well as to create a set of psychological conditions for the formation of theoretical-systemic thinking.

Reshetova (2002) understands that the basis for the integral development of the student's personality does not lie in the mastery of a broad spectrum of versatile knowledge, but rather in the mode of its assimilation and in the possibilities it creates for thinking, which allow the object of study to be understood in its totality, as a system of scientific concepts that crystallize social and historical experience and establish a structure of generalization. This structure provides a theoretical-scientific level of knowledge content, in order to consciously manage students' learning activities in the diversified development of culture and in the transformation of the world. When studying the types of OBA and their effects on intellectual development, Reshetova (2017) also reached the conclusion regarding the positive effect of the systemic structuring of type III orientation and, consequently, of disciplinary content as necessary for Developmental Didactics within the Galperin–Talízina System. The systemic organization of type III orientation and of content is thus grounded in the systemic nature of theoretical thinking (Galperin, 2023).

An important aspect in Chemistry learning is the formation of theoretical thinking in the form of scientific generalizations, expressed through the principles of a systemic approach to the object of knowledge, which is considered the methodological basis for organizing this discipline and the theoretical activity aimed at studying its contents as a system. This characteristic of theoretical thinking is referred to as "systemic" by Reshetova (2002). Núñez and Silva (2019) warn that the formation of theoretical-systemic thinking in basic education students is directly related, among other factors, to teacher education, since part of the difficulties presented by students in developing this type of thinking in Chemistry classes also stems from the teaching practices adopted by instructors.

Since, in Developmental Didactics, the teacher's main activity is to create conditions, organize, and manage effective student learning, aiming at the intellectual development and the personality's harmonious and integral formation, according to Núñez (2026), initial teacher education should contribute to the development of this type of thinking in future teachers. For this reason, the study of the levels of theoretical-systemic thinking among teachers in initial training processes is relevant in research related to Chemistry Education, from the perspective of Developmental Didactics within the Galperin School, as argued by Núñez, Pereira, and Barros (2024).

Considering this importance, this study seeks to answer the following research question: what are the levels of development of theoretical-systemic thinking among Chemistry undergraduates in the final stage of their degree program when they justify the occurrence of chemical reactions?

This research may contribute to the debate on initial teacher education by encouraging, when necessary, the rethinking and organization of processes aimed at fostering the development of teachers' theoretical-systemic thinking, grounded in the theoretical framework addressed in this study.

2 The Systemic Approach and Theoretical-Systemic Thinking Related to Chemical Reactions in the Developmental Didactics of the Galperin School

In Developmental Didactics, within the context of the Galperin School, the systemic approach was configured as an approach aimed at addressing the particularities of the type III orienting basis, characterized by Galperin. According to Talízina (1993), when structuring instructional content according to this type of orientation, it becomes necessary to adopt a systemic approach to the object of study. This approach makes it possible to move beyond the empirical and descriptive level, contributing to students' understanding of the essential laws and relations that structure the object (system of concepts) to be assimilated, thus fostering the formation of theoretical-systemic thinking. Within the Galperin School, these modifications in the structuring of content were carried out based on different approaches: the Genetic-Systemic approach of N. G. Sálmina and the

Functional-Structural Systemic approach of Z. A. Reshetova. In the research conducted by Núñez (1992), there is a combination of these two approaches for Chemistry teaching.

According to Galperin (1986; 2021), orientation is the mental image elaborated by the subject when faced with problem situations, which makes it possible to evaluate them and to develop a strategy of action for solving them based on the circumstances (image of the field of action), as well as, during the resolution process, to correct and regulate the intellectual action being performed. Thus, the intellectual action to be carried out with the concept depends essentially on the type of orientation elaborated by the subject, which, according to Galperin (2001), may assume different types depending on the method of its elaboration, the degree of generalization, and the degree of detail of the elements that compose it.

Among the types of orientation identified by Galperin (2001), type III orientation is characterized by enabling the subject to elaborate, independently, a complete image of the action with a high degree of generalization and detail, which allows for broad transferability to other situations and promotes the rapid formation of theoretical-systemic thinking.

In the Functional-Structural Approach of Z. A. Reshetova, the system of theoretical knowledge, understood as the theoretical body or conceptual core of instructional content that makes it possible to characterize and explain certain objects of study, is organized into a hierarchical system of theoretical concepts (subsystems) within the system as a whole (Reshetova, 2002). The Functional-Structural Approach emphasizes the identification of interacting elements (subsystems) and the determination of their internal structure, hierarchy, relations, and functions in the functioning of the system as a complex and integrated whole. The emphasis lies in the characterization of the constitutive elements and the connections they establish within the system. Reshetova (1987) explains that, from this perspective, the object of study comes to be understood by the student as a totality endowed with specific qualitative properties, possessing its own mechanism of constitution, diverse forms of manifestation, origin, and development. According to the author, the object presents itself in its dialectical logic, and thought, under this logic, also becomes dialectical.

In the understanding of Núñez (1998), the main link to be considered in this approach, as the system-forming relation, is the functional-structural one. This conception presupposes the emphasis on the stable functional characteristics of each subsystem, referred to by Talízina (1993) as invariants, which represent the generalizing nuclei that constitute the essence of the system of concepts to be assimilated and are necessary for solving a set of problem situations belonging to a given class. An invariant, in the conception of Reshetova (2002), constitutes the stable functional structure of each level of the system, which remains preserved across a variety of particular cases considered as variants.

Núñez and Ramalho (2012) understand that, within the Functional-Structural Approach, the aim is to comprehend the essence through the diversity of phenomena that express it. To this end, the object of study is described in its most developed stage, in its totality, with its composition and structure being highlighted, as these determine its mode of functioning within a broader system, as a systemic totality.

Once the method of systemic analysis of objects has been assimilated, highlighting their essential elements, connections, and interrelations, the student may use it as a general method of analysis, applying it to particular cases understood as variants of the assimilated invariant. The concepts formed during the teaching process become integrated into the content of the students' orienting basis, enabling the analysis of any particular variants of a given systemic object (Talízina, 1993; Reshetova, 2017; Núñez; Pereira; Barros, 2024).

Núñez (2009) clarifies that, through the Functional-Structural Approach, the organization of the system of concepts to be assimilated on the basis of generalizing nuclei avoids fragmentation and the excessive accumulation of contents in the curricular component under consideration, without, however, reducing the breadth of the knowledge involved. By enabling the resolution of a set of typical problem situations belonging to a given class, invariants promote the expansion of the structurally organizing concepts effectively assimilated, as an expression of the essence of the conceptual system, which come to integrate students' theoretical-systemic thinking, thereby fostering the formation of thought mediated by concepts that are integrated into the elaborated orienting basis.

DOI: http://doi.org/10.14393/OBv10.e2026-06

Talízina (1993) draws attention to the fact that the construction of the object of study in the form of invariants makes it possible to avoid curriculum overload by increasing its informational capacity, since the assimilation of invariant knowledge opens new fundamental possibilities for independent cognitive activity and for the construction of new knowledge.

The systemic approach and learning according to type III orientation have proven to be pathways that promote: (a) a high level of knowledge solidity; (b) broad transfer of learning to new contexts and areas of knowledge; (c) greater motivation for learning; (d) reduced time required for content acquisition; and (e) a creative attitude among students — all of which are characteristics of theoretical-systemic thinking (Reshetova, 1983, 2017; Sálmina, 1989; Galperin, 1992, 1998; Núñez; Gonzalez, 1996; Vygotskaya; Rekhtman, 2012; Núñez; Silva, 2019).

The systemic approach, as a method for managing the learning of content, develops according to the dialectic from the general to the singular, which finds its meaning in the whole, as explained by Reshetova (2004), constituting a pathway for the formation of theoretical-systemic thinking in Chemistry as a scientific discipline within the school curriculum.

2.1 Theoretical-Systemic Thinking on the Chemical Reaction

The understanding of the chemical reaction as a system, inherent to the nature of Chemistry as a scientific discipline, is recognized by several researchers, including Núñez (1992), Vygotskaya and Rekhtman (2012), and Hedesa (2014), who characterize it as a complex system composed of subsystems. Its essence, according to Núñez (1992), lies in its internal structure and composition, which are decisive in explaining the occurrence of chemical reactions, as well as in accounting for the influence of factors such as the conditions required for their occurrence, the phenomena that evidence them, the energy involved, the rate at which they proceed, the equilibrium state, and their multiple applications.

By determining essence as a generalized manifestation (within certain limits of applicability), it becomes possible to characterize the invariant of chemical reactions as a theoretical-systemic model. Following the logic of Talízina (1993), Reshetova (2002), and Núñez (1992), this makes it possible to shift the focus of study from the diversity of particular chemical reactions to the study of general-essential knowledge. Particular chemical reactions (and their singularities) are studied as a means of mastering the general-essential dimension characteristic of theoretical-systemic thinking.

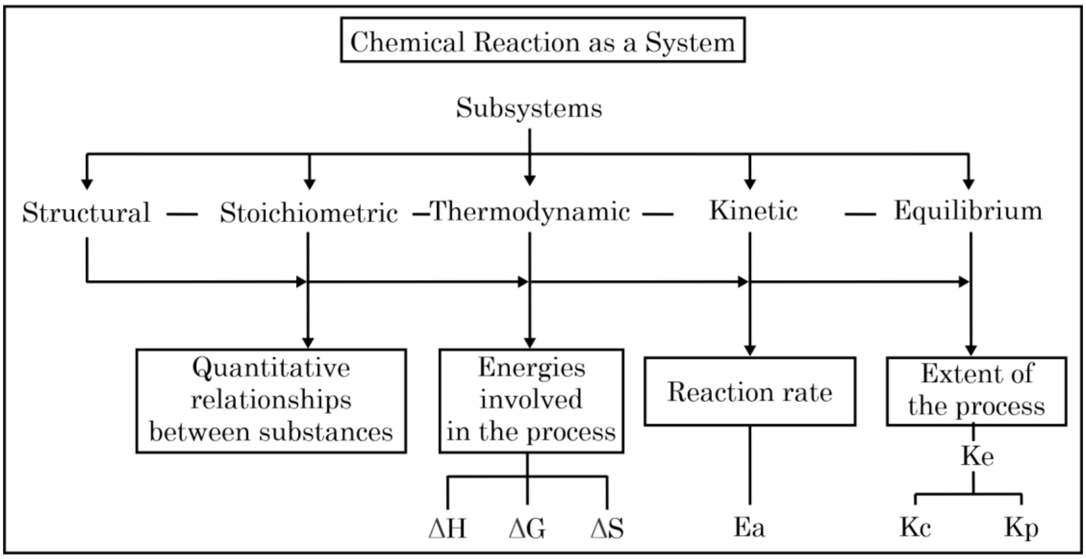
Studying chemical reactions from a theoretical-systemic approach presupposes considering the multiple contradictions among the theoretical models that ground the justification of the occurrence of processes under different conditions. In other words, it involves addressing the limitations of these models, which do not explain certain aspects of chemical reactions and therefore generate contradictions within each subsystem, requiring the establishment of new systemic relations. It is, therefore, an analysis at a theoretical level that goes beyond the empirical description of phenomena and seeks to understand their internal determinations, their essence, in a holistic and complex way.

From a theoretical-systemic perspective, Núñez (1992) understands the chemical reaction as a global process of transformation of substances under specific conditions, in which the subsystems of substance composition and structure, stoichiometry, thermodynamics, kinetics, and chemical equilibrium are articulated. According to the author, these are subsystems that cannot be dissociated in the integrated understanding of the reaction.

Based on this understanding of Núñez (1992), Pereira (2024) defines the chemical reaction from a systemic perspective as the process of transformation of one or more substances (or initial materials) under specific conditions, in which structural modifications occur giving rise to one or more substances (or new materials), which combine in constant proportions, and which is characterized by energy changes as well as by a given rate and extent.

Figure 1 presents the content of the concept of chemical reaction from a systemic perspective, that is, as a complex system integrated by subsystems that are interrelated and functionally articulated within a conceptual invariant of the content, in order to explain the system as a whole.

Figure 1 – Representation of the Conceptual System of the Chemical Reaction as a System



Source: Pereira (2024)

The conceptual scheme presented in Figure 1 makes explicit the necessary and sufficient characteristics that constitute the invariant of the concept of chemical reaction from a theoretical-systemic perspective. Reshetova (2002) explains that this type of systemic conceptual scheme is the antithesis of fragmented and merely accumulative approaches, which lack a unifying theoretical-systemic totality. In such approaches, although the subsystems that compose the system may be mentally analyzed in isolation, they must be understood in their articulation and integration, as a reflection of their systemic properties.

Reshetova (2002) argues that the organization of the object of knowledge as a system, in this case, the chemical reaction, can be described through two languages: the language of systems analysis categories and the language of Chemistry concepts as a scientific discipline. The language of systems analysis highlights categories that designate systemic properties (subsystem, element, level, integrity, complexity, connections, organization, structure, hierarchy, coordination, subordination), which guide the revelation of the object in its most general form as a system. The language of Chemistry, as a science, theoretically describes the content of the object as a system, as well as each of its subsystems and their relationships. In this way, it appears as generalized knowledge at the methodological level, from which the system of concepts is then organized.

The study of the chemical reaction under the systemic approach enables its understanding as a combination of interrelated levels, revealing the laws that govern the generation of the full diversity of possible phenomena (chemical reactions), the essential properties of the system, and the laws that govern its existence, functioning, and development.

The systemic analysis of the reaction — that is, the integration of its subsystems: composition and structure of substances, amounts of substances, thermodynamics (ΔG, ΔH, ΔS), kinetics (E_a), and chemical equilibrium (K_c, K_p) — makes it possible to justify whether the reaction will occur or not under certain conditions, thereby favoring or not favoring these processes according to the needs of technology, science, and even everyday life. Núñez (1992) understands that this type of analysis allows the establishment of the most appropriate conditions (and thus the optimization of the process) for a reaction to occur under given circumstances. In the same perspective, Pereira (2024) states that this approach can enhance the development of the systemic dimension of theoretical thinking, which is fundamental for understanding Chemistry as a science.

According to Núñez, Pereira, and Barros (2024), theoretical thinking is understood by Galperin as the orientation elaborated by the subject for intellectual activity, directed toward the resolution of problem situations on the basis of theoretical concepts, which enables the planning, execution, control/regulation, evaluation, and correction of the problem-solving process. Conceptual orientation, as a functional dimension of theoretical thinking, is revealed as an orienting image that has a specific content (theoretical concepts, system of actions and operations, conditions, and tools) for the activity, as well as a specific structure that Galperin (1992) termed the operational model of thinking.

Building on this idea, theoretical-systemic thinking refers to an orientation based on concepts of a theoretical-systemic nature, elaborated by the student to solve problem situations involving a certain degree of systemic complexity. In this type of thinking, concepts are articulated within a “macro-system,” highlighting the system-forming connections among them, which enables a systemic orientation for formulating, planning, and solving the problem, as well as for regulating the process.

Shragina (2011) argues that a person who possesses an adequate level of theoretical-systemic thinking perceives, in any object, a whole organized into parts and seeks to understand the ordering of these parts within the whole, which enables them to master tools of theoretical thinking of a general and universal nature, transferable to different fields of knowledge. For the author, theoretical-systemic thinking is configured as a style of thinking opposed to empirical thinking. As theoretical-systemic, Shragina (2011) proposes considering thinking whose level of development, in the activity of cognition of the world by an individual, allows the establishment of connections between objects and phenomena of objective reality, the identification of patterns in order to predict, produce, and explain them.

Theoretical-systemic thinking can be defined as the subject's orientation toward a type of cognitive, analytical, and conscious activity, in which the subject, when internalizing a given object of reality, does so in the form of a system. In this process, the systemic properties and relations among the elements (its invariant) that constitute it are made explicit. The theoretical-systemic thinking related to the chemical reaction constitutes a type III orienting image (necessarily systemic), composed of a systemic conceptual content (model of the object) and a system of actions and operations (model of the action). The articulation between these two dimensions (conceptual and operational) makes it possible to understand, plan, and solve systemic problem situations, that is, situations that require theoretical-systemic thinking for their resolution.

Considering the studies of Núñez (1992), Reshetova (2002), and Pereira (2024), a model of theoretical-systemic thinking was established for the intellectual action of justifying chemical reactions as a system, as well as the system of actions and operations necessary for the systemic concepts modeled in the invariant, which constitutes the model of the action. This model of thinking, presented in Table 1 as an expression of a type III orientation (Scheme of the Complete Orienting Basis of Action — SCOBA), may serve as a reference for the diagnosis and formation of theoretical-systemic thinking.

Table 1 – Operational Model of Theoretical-Systemic Thinking: The Action of Systemically Justifying Whether Chemical Reactions Occur

Model of the Object	**Model of the Action**		
	Actions		**Operations**
To justify chemical reactions as a system is to elaborate and relate, in a dialectical manner, arguments that make it possible to understand, in a theoretical-systemic way, why a chemical reaction, under certain conditions, occurs or does not occur.	To interpret	Action 1. Interpret the information related to each subsystem on the basis of theoretical models in Chemistry.	O1 – Interpret the reaction in thermodynamic terms (ΔG; ΔH; ΔS); O1.1 – Interpret the value of the parameter ΔG; O1.2 – Interpret the value of the parameter ΔH; O1.3 – Interpret the value of the parameter ΔS; O2 – Interpret the reaction in kinetic terms; O3 – Interpret the reaction in terms of chemical equilibrium Ke (Kc or Kp).
	To realate	Action 2. Relate the different subsystems from a dialectical perspective.	O1 – Develop an argument based on the relationship between the thermodynamic subsystem and the kinetic subsystem; O2 – Develop an argument based on the relationship between the kinetic subsystem and the equilibrium subsystem.
	To synthesize	Action 3. Synthesize the arguments from Action 2 and systemically justify the occurrence or non-occurrence of the reaction under the given conditions.	O1 – Synthesize the arguments from Action 2 and systemically justify the occurrence or non-occurrence of the reaction under the given conditions.

Source: Pereira (2024)

It is necessary to emphasize that the operational model of theoretical-systemic thinking for the action of systemically justifying whether chemical reactions occur must ensure that the subject is able to:

- become aware of the nature, structure, and composition of the system (the chemical reaction), which is revealed as an invariant for systemically thinking about a wide range of chemical reactions;
- understand and think according to the connections established among the subsystems, becoming aware of the need for their integration in order to address the problem situation that requires theoretical-systemic thinking.

The model of the object (the conceptual meaning of the chemical reaction as a system) and the model of the action (the system of operations for the action of justifying the chemical reaction as a system, as defined in this article) make it possible to solve a set of systemic problem situations representative of a broad class of chemical reactions.

3 Methodology

The diagnosis of theoretical-systemic thinking is based on the methodology for characterizing professional teaching thinking developed by Núñez, Ramalho, and Pereira (2024), grounded in studies on the formation of intellectual actions and concepts by Galperin (2023). In this study, the thinking under analysis is characterized as a product of the professional training of undergraduates in a Chemistry Teacher Education program, that is, as a level of actual development, according to the concept of the Zone of Proximal Development by Vygotsky.

The conception of diagnosis on which the methodology is based follows a qualitative-developmental perspective, in which diagnosis aims to reveal, through hypotheses, the internal structure of the cognitive activity of future Chemistry teachers when solving certain tasks of a systemic nature, oriented toward the identification of levels of intellectual development related to the concept of the chemical reaction as a system.

According to the methodology of Núñez, Ramalho, and Pereira (2024), the study of theoretical-systemic thinking is organized into the following stages: (a) definition of the general action required for theoretical-systemic thinking based on the concept of the chemical reaction as a system; (b) definition of the operational model of the general action (SCOBA); (c) design of tasks (pedagogical test) in a valid and reliable manner; (d) application of the pedagogical test; (e) analysis of students' responses according to the operational model of thinking used as a reference; (f) characterization of the theoretical-systemic thinking of the undergraduates based on their responses to the tasks in the pedagogical test.

The model of thinking (SCOBA), based on Galperin's theoretical system, provides a key methodological principle for analyzing the level of development of thinking, since, as a reference, it makes it possible to characterize thinking that mobilizes the theoretical-systemic concept of the chemical reaction and its subsystems, as well as the general actions through which the systemic relations integrating the parts are carried out in order to solve the systemic task. In this way, diagnosis is not limited to the outcome of the general action, but seeks to understand its orienting structure.

Twelve undergraduate students (identified by codes — L1 to L12 — to ensure confidentiality of the information) participated in the study. They were enrolled in the course Supervised Internship for Teacher Education for Secondary Education, offered in the 8th and final semester of the in-person Chemistry Teacher Education program at the Federal University of Rio Grande do Norte (UFRN), Natal Campus.

As a data collection instrument, a pedagogical test composed of two questions, presented in Table 2, was used.

Table 2 – Design of the Pedagogical Test

Objective	**Question**
To identify and characterize the conceptual object model (system of concepts) of the undergraduates regarding each of the subsystems of the chemical reaction.	Consider the values of the following parameters related to the synthesis reaction of ammonia: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ T = 298 K P = 1 atm $\Delta H_f° = -92$ kJ/mol; $\Delta G_f° = -16$ kJ/mol; $\Delta S_f° = -198.75$ J/K Kp = 0.00001 Assuming also that the reaction has a high activation energy in the slow step of the reaction, answer the following question: What information regarding the occurrence or non-occurrence of the reaction is provided by each of these parameters?
To characterize the systemic relations established by the undergraduates to justify the occurrence of the chemical reaction.	Using all the information from the parameters presented below in an integrated manner, justify why, under these conditions, ammonia production is not feasible in industry: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ T = 298 K P = 1 atm $\Delta H_f° = -92$ kJ/mol; $\Delta G_f° = -16$ kJ/mol; $\Delta S_f° = -198.75$ J/K Kp = 0.00001 High activation energy in the slow step of the reaction.

Source: Pereira (2024)

In question 1, the undergraduates were expected to assign meaning to the values of the subsystem parameters and indicate which information could be obtained from each of them. The question made it possible to analyze and characterize the meanings attributed to the conceptual dimension of theoretical-systemic thinking, that is, the conceptual content that integrates the students' orienting image and characterizes the model of the object of the diagnosis.

Responses were classified as correct (C) when the parameter (ΔH, ΔS, ΔG, Kp, and Ea) was appropriately interpreted, that is, when correct meanings were attributed to each of them; incorrect (I), when the parameter was not correctly interpreted; or not answered (NR), when no response was provided. Based on the analysis of the responses, quality criteria were established and organized into three levels: "high" (H), when all parameters were correctly interpreted; "medium" (M), when only one of the five parameters was incorrectly interpreted; and "low" (L), when two or more parameters were incorrectly interpreted. Within these categories, a qualitative dimension is observed, since inaccuracies in the interpretation of a parameter generate errors that inevitably lead to inadequate interpretations of the system.

Question 2 presented a systemic problem situation in which the undergraduates were expected to justify whether the ammonia synthesis reaction would occur under the given conditions, establishing, for this purpose, relations among the subsystems in order to elaborate an integrated theoretical-systemic orientation for solving the task, which is indicative of the theoretical-systemic thinking under investigation. This question required three essential actions from the operational model of theoretical-systemic thinking used as a reference, related to the subsystems of the reaction (kinetic, thermodynamic, and equilibrium): interpreting the information related to each subsystem based on theoretical models in Chemistry; relating the different subsystems from a systemic perspective, recognizing the potentialities and limitations of each one; and synthesizing the arguments and justifying, in a theoretical-systemic manner, the occurrence or non-occurrence of the reaction under the given conditions.

Three levels of quality of systemic thinking were established for the undergraduates' responses, based on the actions performed: "high" (H), when the actions of interpreting, relating, and synthesizing were appropriately carried out in the justification of the task solution; "medium" (M), when the actions of interpreting and relating were correctly performed; and "low" (L), when the action of interpreting was not correctly performed, the established relations were inadequate, as well as the systemic synthesis of the response to the problem. The presence or absence of these actions and operations in the responses is an indicator of the levels of theoretical-systemic thinking of the undergraduates when justifying the presented reaction.

According to the guidelines of Núñez, Ramalho, and Pereira (2024), the validity and reliability of the pedagogical test and of the results obtained are confirmed by the theoretical grounding of the research problem, by the adequacy of the methodology to its objectives, and by the definition of quality criteria for the object of study, which are discussed and validated by an experienced researcher in the theme under investigation.

The analysis of students' responses to the two questions of the pedagogical test made it possible to characterize both the theoretical-systemic conceptual dimension, expressed in the interpretation of the parameters of the reaction subsystems, and the general action of justifying the chemical reaction as a system, evidenced in the articulation among the subsystems and in the synthesis of the arguments presented in the elaborated justification, with reference to the operational model of thinking (SCOBA).

An analysis of the errors present in the undergraduates' responses was also carried out as a way of characterizing theoretical-systemic thinking, considering that errors, according to Galperin (2023), may be related to inadequate orientations for solving the proposed problem situations.

4 Levels of development of theoretical-systemic thinking among Chemistry undergraduates regarding chemical reactions

The results of the study and their analyses are presented in accordance with the formulated objectives, which are related to the questions of the pedagogical test, namely, to characterize the levels of development of theoretical-systemic thinking of future Chemistry teachers in the final stage of their initial teacher education.

The first question of the pedagogical test presented parameters that allow for the characterization of the subsystems of a chemical reaction: thermodynamic, kinetic, and equilibrium, which constitute the object of study in the Chemistry course and are necessary for the theoretical-systemic thinking under investigation. The question included items whose answers evidenced the conceptual meaning attributed by the undergraduates to the system of concepts that compose the definition of the chemical reaction as a system, understood as one of the languages required to describe the content of the object of study. The meanings attributed by the undergraduates to each parameter (ΔH, ΔS, ΔG, Ea, Kp) were evaluated.

Table 3 presents the evaluation of the conceptual meanings attributed by the undergraduates to the defined subsystems, classified as correct (C), incorrect (I), or not answered (NR). A global evaluation is also presented, integrating and characterizing the quality levels of the responses to the question, which, as described in the methodology, were categorized as: “high” (H), when the undergraduate correctly attributed the conceptual meaning to all subsystems; “medium” (M), when the meaning of one subsystem was not correctly attributed; and “low” (L), when the meaning of two or more subsystems was not correctly attributed.

Table 3 – Quality Levels of Undergraduates' Responses

Undergraduate	**ΔH**	**ΔS**	**ΔG**	**Kp**	**Ea**	**Quality Levels**
L1	C	C	C	C	C	H
L2	C	C	C	C	C	H
L3	NR	NR	NR	NR	NR	—
L4	C	I	C	C	C	M
L5	I	I	C	C	C	L
L6	C	C	C	C	C	H
L7	C	C	C	C	C	H
L8	C	C	C	C	C	H
L9	C	I	I	C	I	L
L10	C	C	C	C	C	H
L11	C	C	C	C	C	H
L12	C	C	C	C	C	H

Source: Pereira (2024)

According to the data presented in Table 3, eight undergraduates provided correct answers for all parameters of the chemical reaction subsystems, which is why they are classified at the "high" (H) level.

This result shows the undergraduates' mastery of the meaning of these terms for interpreting the values of the subsystems ΔH, ΔS, ΔG, Ea, and Kp under the given conditions. The undergraduates are able to explain that ΔH refers to the release of energy in the form of heat during the chemical transformation process, that $\Delta G < 0$ indicates that the reaction is spontaneous, and that Kp indicates the extent, that is, the degree to which products or reactants are favored in a reaction at equilibrium.

> ΔH indicates the endothermic or exothermic nature of the reaction. In this case, the reaction occurs with energy release (L7, 2022).
> $\Delta G < 0$ indicates that the ammonia formation process is spontaneous (L2, 2022).
> The equilibrium constant in terms of pressure (Kp) = 0.00001 corresponds to an equilibrium that is shifted toward the reactants. This confirms that the reaction only occurs under specific pressure and temperature conditions (L8, 2022).

DOI: http://doi.org/10.14393/OBv10.e2026-06

L4 incorrectly interpreted the value of ΔS, which is why this student was classified at the “medium” (M) level. Two undergraduates showed difficulties in answering the question correctly and were classified at the “low” (L) level: L5 and L9, respectively. As indicated in Table 3, L3 did not answer this question.

Regarding the conceptual errors of the undergraduates in the diagnosis of levels of theoretical-systemic thinking, it is important to identify and characterize them, since they may be related to learning difficulties. The errors identified in the responses were analyzed due to their relevance in the study of theoretical-systemic thinking, as, according to Galperin (2002), they may reflect inadequate orientations for solving problem situations.

The undergraduates L4, L5, and L9 made errors in their responses by associating the spontaneity of the reaction with the negative value of ΔH°; by associating the value of ΔS° = −198.75 J/K with a high degree of organization of the reactants; by relating the negative value of ΔS° in the Gibbs equation to a positive ΔG°; by indicating that ΔS° provides the temperature of the reaction; by stating that ΔG° provides the values of enthalpy, entropy, and temperature of the reaction; and by indicating that Ea provides the equilibrium constant and the temperature of the reaction.

Of the six errors made by the undergraduates, five are related to the thermodynamic subsystem, three of which result from the incorrect interpretation of the ΔS° value.

> It indicates that work is required for the reaction to occur, since the negative value implies that the reactants have a high degree of organization (L4, 2022).
> A negative ΔH° value indicates that the reaction is spontaneous (L5, 2022).
> Substituting the negative ΔS° value into the Gibbs equation yields a positive ΔG°, thus indicating a non-spontaneous reaction (L5, 2022).

As presented, L4 incorrectly relates the value ΔS° = −198.75 J/K to a high degree of organization of the reactants. This error stems from the fact that entropy represents the degree of disorder, or randomness, of the system, which decreases as ammonia is formed, since the entropy of the reactant molecules (N_2 and H_2) is higher compared to that of the product molecule NH_3.

L5, in their response, incorrectly associates the negative value of ΔH° with the spontaneity of the reaction, an error that frequently appears in various studies, such as that by Johnstone, MacDonald, and Webb (1977), which investigated the understanding of 98 students and revealed that a large proportion believed that endothermic reactions cannot occur spontaneously.

In another response by L5, an error is observed in the relationship established between the negative value of ΔS° and a positive ΔG° in the Gibbs equation. This interpretation disregards that, in situations in which both ΔH° and ΔS° are negative, the value of ΔG° can be negative, provided that the TΔS term is smaller in absolute value than ΔH°.

The errors observed in question 1 of the pedagogical test have important implications for the justification of whether the chemical reaction occurs or not. When the meaning of one of the subsystems is incorrectly interpreted (for example, by assuming that ΔH indicates the spontaneity of the reaction), the adequate analysis of the chemical reaction as a system is compromised, given the importance of each of these subsystems in the systemic analysis and, consequently, in the correct justification of whether the reaction will occur or not under the given conditions, as well as in the possibility of influencing the process.

In a formative process grounded in Galperin's theoretical system, in light of type III orientation, learning is not only enhanced but also occurs with a minimum of errors, since the SCOBA, as an operational reference model, allows the process to be regulated. This contributes to the development of critical thinking, enabling the student to evaluate the situation, identify conceptual errors, and recognize information that is inadequate to the concept. In this way, errors become part of the self-regulation developed by the student in the process of solving the problem situation, that is, in justifying the chemical reaction as a system.

To justify why a chemical reaction occurs or does not occur, from the perspective of the theoretical-systemic approach, implies not only understanding the structural elements (subsystems) separately but also, fundamentally, integrating the relationships established among them, producing new systemic qualities specific to the object of study (the chemical reaction), which cannot be explained by the subsystems in isolation.

If, in question 1 of the pedagogical test, the undergraduates were expected to express their understanding of the meanings of the conceptual content of each subsystem of the chemical reaction as a system, in question 2 the aim was to assess the actions for establishing systemic relations among these conceptual contents, as a manifestation of theoretical-systemic thinking.

In question 2, the undergraduates, by integrating the subsystems of the chemical reaction, were expected to justify the non-occurrence of ammonia synthesis under the presented conditions. In solving the problem situation, they would need to interpret the characteristic parameters of each subsystem and relate the information, understanding the limitations of each one and the need to articulate their potentialities, as well as to establish new conceptual relations in order to promote the emergence of new qualities of a systemic nature in the synthesis action, which allow responding to the theoretical-systemic problem situation.

Table 4 presents the results of the assessment of the actions and operations performed by the undergraduates when answering question 2 of the pedagogical test, classified as: correct (C), partially correct (PC), incorrect (I), and absent (A), that is, operations that were not carried out to answer the question, considering the SCOBA model adopted as a reference for the theoretical-systemic thinking in this study.

Table 4 – Actions and Operations Used by Undergraduates to Justify the Non-Occurrence of the Reaction

Undergraduate	**Action 01**						**Action 02**		**Action 03**
	To interpret						**To relate**		**To synthesize**
	O1	**O1.1**	**O1.2**	**O1.3**	**O2**	**O3**	**O1**	**O2**	**O1**
L1	PC	A	C	A	C	C	C	C	A
L2	A	A	A	A	A	A	A	A	A
L3	A	A	A	A	A	A	A	A	A
L4	PC	A	C	A	C	C	C	C	A
L5	PC	C	A	A	C	A	C	A	A
L6	C	C	C	C	C	C	C	C	A
L7	PC	C	A	A	C	C	C	C	A
L8	A	A	A	A	A	A	A	A	A
L9	PC	C	A	A	A	A	A	A	A
L10	A	A	A	A	A	A	A	A	A
L11	PC	A	C	A	C	A	C	A	A
L12	PC	C	A	A	C	C	C	C	A

Source: Pereira (2024)

According to Table 4, regarding the action of interpreting, L6 performed all the operations associated with this action correctly (C). In other words, this undergraduate recognizes the theoretical-conceptual meaning of the parameters that characterize each of the subsystems.

In the responses of the other undergraduates, it was found that, in addition to absent operations (A), particularly regarding the entropy parameter in the thermodynamic subsystem, there were partially correct operations, since they presented the interpretation of only some thermodynamic parameters, such as ΔG or ΔH, while neglecting ΔS, which was the most frequently absent parameter in the undergraduates' interpretations, appearing only in L6's response.

Interpreting the reaction parameters, that is, correctly attributing the conceptual meaning to each of the subsystems, is essential for the theoretical-systemic analysis, since the incorrect interpretation of any of these parameters compromises the analysis of each subsystem and its function within the whole.

The analysis of the responses reveals important aspects of the undergraduates' theoretical-systemic thinking. The responses evidenced the

DOI: http://doi.org/10.14393/OBv10.e2026-06

absence of interpretation of parameters necessary to justify the non-occurrence of the ammonia synthesis reaction under the presented conditions. This gap is evident in the responses of L1, L7, and L12, in which none of them correctly refers to the value of ΔS of the reaction.

> It is not feasible in industry due to the low yield evidenced by the low Kp value and the high activation energy value (a very slow reaction). Using this same parameter, we can see that if we increased the pressure, we would shift the equilibrium toward ammonia formation, increasing Kp. However, the obstacle would be the increase in temperature, since the reverse reaction is endothermic, thus causing the equilibrium to shift toward the reactants (L1, 2022).

In addition to not referring to the value of ΔS, L1 also does not interpret ΔG, a thermodynamic parameter necessary to determine the spontaneity of the reaction under the presented conditions. The absence of this parameter compromises the systemic analysis of the reaction. L7 and L12, in turn, omit ΔH from their responses, another parameter necessary to systemically justify the occurrence of chemical reactions.

> The fact that there is a high activation energy value and that no suitable catalyst was provided to reduce it already indicates that the reaction will not occur. The equilibrium constant for these data indicates that there is no progress in the reaction toward ammonia formation. The ammonia synthesis reaction occurs at high pressures and temperatures, whereas in the given data the temperature and pressure are at ambient values. Despite a negative ΔGf°, which favors the reaction, these conditions do not favor the industrial production of ammonia (L7, 2022).
> Although the Gibbs free energy is less than zero and indicates spontaneity and, therefore, a thermodynamic favorability for the reaction, we observe that the reaction equilibrium, through Kp, indicates a favorability of the equilibrium of partial pressures toward the reactants. Furthermore, the high activation energy value shows that the reaction is kinetically unfavorable (L12, 2022).

The action of relating required the undergraduates to elaborate arguments based on the relationship between the thermodynamic and kinetic subsystems (O1), as well as between the kinetic and equilibrium subsystems (O2). In operation 1, seven undergraduates responded correctly (L1, L4, L5, L6, L7, L11, and L12), whereas in operation 2, five (L1, L4, L6, L7, and L12) correctly related the kinetic subsystem to the chemical equilibrium subsystem. L2, L3, L8, L9, and L10 did not establish a relationship between any of the subsystems.

Correctly relating the reaction subsystems, taking into account the contradictions among the theoretical models of Chemistry in order to justify the whole, is an essential characteristic of theoretical-systemic thinking. This relationship must be established considering that: (1) although chemical reactions occur with a decrease in the total energy of the system, some reactions, even if exothermic, are neither spontaneous nor do they occur under the given conditions; (2) although some reactions are spontaneous, it is not possible to observe their occurrence under practical conditions (thermodynamically favorable and kinetically unfavorable processes); and (3) although some reactions present low activation energy, at equilibrium the concentration of products is relatively low compared to that of the reactants, which requires a synthesis of the contributions of each subsystem to explain the process as a system (Pereira, 2024).

To synthesize implies elaborating a systemic justification in which the different reaction subsystems do not appear in isolation, but rather integrated into a totality, considering the established relationships and producing integrative properties that make it possible to justify whether the reaction occurs or not, under which conditions it occurs, and whether it is observable in practice. Synthesis enables the elaboration of consistent and well-founded arguments to justify the occurrence or non-occurrence of the reaction, which reveals levels of theoretical-systemic thinking as the subject's orientation when solving a given theoretical-systemic problem situation. With regard to this action, none of the undergraduates synthesized the arguments elaborated from the relationships established among the subsystems in order to justify, based on the contradictions among thermodynamics, kinetics, and equilibrium, the non-occurrence of the ammonia production reaction under the presented conditions. This reveals difficulties among the undergraduates in elaborating explanatory models to systemically justify the non-occurrence of the reaction.

No undergraduate was classified at the "high" level, since all participants failed to synthesize and ground their justification in the potentialities and limitations (contradictions) inherent to the reaction subsystems, that is, in the contradictions among the theoretical models of thermodynamics, kinetics, and equilibrium. L6, who correctly performed the actions of interpreting and relating, was classified at the "medium" level. As for the other undergraduates (L1, L2, L3, L4, L5, L7, L8, L9, L10, L11, and L12), they were classified at the "low" level, as they did not correctly interpret the information related to the subsystems, thus establishing inadequate relations and failing to perform a systemic synthesis in solving the problem situation.

Final Considerations

In Developmental Didactics grounded in the Galperin–Talízina System (or, preferably, in the terms of Núñez, Pereira, and Barros (2024), the School of Galperin), theoretical thinking has a systemic character, which allows it to be designated as theoretical-systemic thinking, being the result of intentional, conscious, and regulated formation in the context of effective learning.

Theoretical-systemic thinking related to the chemical reaction constitutes an objective of Chemistry education in Basic Education. Consequently, the teaching activity of the Chemistry teacher must be oriented toward the organization of content and the use of teaching methods that foster this type of thinking in students, which requires adequate teacher training for this purpose. For this reason, attention must be given to the development of professional teaching thinking. In this way, theoretical-systemic thinking should be established as an object of intentional and conscious formation throughout the Chemistry Teacher Education program.

The results presented in this article revealed information about the levels of theoretical-systemic thinking of the participants when justifying the occurrence of chemical reactions. Among the main aspects identified, the following stand out: difficulties in establishing integrative relationships among the subsystems; and, in general, limitations in justifying the occurrence of chemical reactions based on the contradictions present in the theoretical models of Chemistry.

These results indicate low levels of theoretical-systemic thinking related to the chemical reaction, that is, difficulties in solving the proposed task. They may be interpreted as resulting from inadequate systemic orienting bases for the required actions, associated with several factors, among which the following stand out: the frequent fragmentation of content (theoretical models) related to the study of chemical reactions in teacher education programs; and the limited emphasis given to theoretical-systemic thinking as an object of study. In the field of Chemistry, this type of thinking is essential not only for understanding why chemical reactions occur, but also for grasping the discipline in its entirety, given that this topic occupies a central position within this curricular component.

It is considered relevant to conduct further research from the perspective of Developmental Didactics within the School of Galperin, highlighting the need to diversify studies on the diagnosis of theoretical-systemic thinking, articulating the relationships between this diagnosis and new training processes oriented toward the development of the professional thinking of future Chemistry teachers, since the teacher's professional thinking, as a result of formative, developmental, and professional teaching, influences the quality of teaching practice.

The theoretical-systemic organization of the contents of professional activity makes it possible to redesign training processes by articulating disciplines, as subsystems, with the object of training understood as a complex and dialectical system, so that each discipline performs its role in the formation and development of theoretical-systemic thinking in future Chemistry teachers.

Considering the context of the study, characterized by a small number of participants and by meetings and activities conducted remotely, it is suggested that these investigations be expanded, as well as the number of diagnostic tasks, especially since research within this approach is still incipient in Brazil.

Diagnóstico del pensamiento teórico-sistémico de estudiantes de licenciatura en Química en la Didáctica Desarrolladora: contribuciones de la Escuela de P. Ya. Galperin

RESUMEN

En la Didáctica Desarrolladora, con base en las contribuciones de P. Ya. Galperin y de su escuela, se destaca la importancia del pensamiento teórico-sistémico de los profesores en la resolución de situaciones-problema que exigen la elaboración de una orientación como elemento estructural de la actividad intelectual del pensamiento profesional docente, esencial para la formación y el desarrollo del pensamiento científico de los estudiantes de la educación básica en las clases de Química. En este trabajo, se tuvo como objetivo caracterizar los niveles de pensamiento teórico-sistémico de estudiantes de licenciatura en Química al justificar la ocurrencia o no de reacciones químicas. Para ello, se realizó una investigación basada en la metodología de caracterización del pensamiento profesional docente, desarrollada por Núñez, Ramalho y Pereira (2024), fundamentada en los estudios de P. Ya. Galperin (2023) sobre la formación de las acciones intelectuales y de los conceptos. Como instrumento de recolección de datos, se utilizó una prueba pedagógica compuesta por dos preguntas. Los resultados del análisis indican que, aunque los estudiantes de licenciatura comprenden el significado de los parámetros de una reacción química cuando se interpretan por separado, presentan dificultades para integrarlos y para justificar, de manera sistémica, la ocurrencia de reacciones en determinadas condiciones. Tales resultados sugieren bajos niveles de pensamiento teórico-sistémico entre los participantes de la investigación en lo que se refiere a la justificación de la ocurrencia o no de reacciones químicas, lo que evidencia la importancia de considerar el desarrollo del pensamiento teórico-sistémico como objeto de formación intencional y consciente en el proceso de formación y profesionalización docente, especialmente en perspectivas formativas orientadas a potenciar la formación intelectual de los profesores.

Palabras clave: Pensamiento Teórico-Sistémico. Enfoque Sistémico. Diagnóstico. Reacciones Químicas. Didáctica Desarrolladora.

4 References

GALPERIN, P. Ya. *Sobre o método de formação por etapas das ações intelectuais*. In: ILIASOV, I. I.; LIAUDIS, V. Ya. (Orgs). Antología de La Psicología Pedagógica y de Las Edades. La Habana: Editorial Pueblo y Educación, 1986. p. 114-118.

GALPERIN, P. Ya. Stage-by-Stage Formation as a Method of Psychological Investigation. *Journal of Russian and East European Psychology*, v. 4, n. 30, p. 60-80, 1992.

GALPERIN, P. Ya. *Psicologia como uma ciência objetiva*. Moscou: Editora do Instituto de Psicologia Prática, 1998.

GALPERIN, P. Ya. *Tipos de orientación y tipos de formación de las acciones y de los conceptos*. In: ROJAS, L. Q. (Comp.). La Formación de las Funciones Psicológicas durante el desarrollo del niño. Tlaxcala: Editora Universidad Autónoma de Tlaxcala, 2001. p. 41-44.

GALPERIN, P. Ya. *Palestras sobre psicologia*. Moscou: Casa do Livro Universidade, 2002.

GALPERIN, P. Ya. *Psychological Grounds of the Development of Ideal Actions and Concepts. Lecture 5*. In: ENGENESS, I (ed.). P. Y. Galperin's Development of Human Mental Activity: Lectures in Educational Psychology. Springer, 2021. p. 65-74.

GALPERIN, P. Ya. *Palestras de Psicologia*. Série: Livro universitário clássico. Ed. 6. Moscou: Universidade Estadual de Moscou, 2023.

HEDESA, Y. J. P. *La enseñanza de la Química y la esencia de la reacción química*. In: VIII Congreso Internacional Didácticas de las Ciencias e XIII Taller Internacional sobre la Enseñanza de la Física, 2014, Havana. Didácticas de las Ciencias: nuevas perspectivas (Quinta parte). Havana, 2014. p.189-200.

HRIN, T. N.; MILENKOVIC, D. D.; SEGEDINAC, M. D.; HORVAT, S. Enhancement and assessment of students systems thinking skills by application of systemic synthesis questions in the organic chemistry course. *J. Serb. Chem. Soc*, v. 81, n. 12, p. 1455-1471, 2016. DOI: https://doi.org/10.2298/JSC160811097H.

JOHNSTONE, A. H.; MACDONALD, J. J.; WEBB, G. Misconceptions in school thermodynamics. *Physics Education*, p. 248-250, 1977.

MAHAFFY, P. G.; KRIEF, A.; HOPF, H.; MEHTA, G.; MATLIN, S. A. Reorienting chemistry education through system thinking. *Nature Reviews Chemistry*. v. 2, n. 16, p. 45-63, 2018. DOI: https://doi.org/10.1038/s41570-018-0126.

NÚÑEZ, I. B. *Sistema Didáctico para la enseñanza de la Química General*. 227 p. Tese (Doutorado em Ciências Pedagógicas) – Instituto Superior Politécnico Jose Antonio Echeverria, La Habana, 1992.

NÚÑEZ, I. B. La formación de la habilidad en la construcción e interpretación de diagramas de fases según teoria de P. Ya. Galperin. *Didáctica de las ciências experimentales y sociales*, n. 12, p. 91-107, 1998.

NÚÑEZ, I. B. *Vygotsky, Leontiev e Galperin: formação de conceitos e princípios didáticos*. Brasília: Liber Livro, 2009.

NÚÑEZ, I. B. *A prontidão profissional docente, a função semiótica e o desenvolvimento do pensamento teórico de estudantes em aulas de ciências e matemática*. Projeto de pesquisa apresentado ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq)), 2026.

NÚÑEZ, I. B.; GONZALEZ, O. P. La estructuración de los contenidos de la disciplina Química General. Una nueva propuesta. *Química Nova*. v. 19, n.5. p. 558-562, 1996.

NÚÑEZ, I. B.; PEREIRA, L. F.; BARROS, S. C. B. *Formação do pensamento conceitual como atividade cognoscitiva da personalidade no contexto escolar: aproximações à Escola de P. Ya. Galperin*. Goiânia: Phillos Academy, 2024.

NÚÑEZ, I. B.; RAMALHO, B. L. *Desarrollo de una unidad didáctica para el estudio de los procesos de oxidaciónreducción en el pre-universitario: contribuciones de la teoría de P. Ya. Galperin*. In: SILVA, M. G. L.; MOHR, A.; ARAÚJO, M. F. F. (Orgs.). Temas de Ensino e Formação de Professores de Ciência. Natal: EDUFRN, 2012. p. 153-180.

NÚÑEZ, I. B.; RAMALHO, B. L.; PEREIRA, L. F. Diagnóstico do pensamento profissional docente como atividade orientadora. Contribuições do sistema teórico de P. Ya. Galperin. *Obutchénie. Revista de Didática e Psicologia Pedagógica*, v. 8, p. 1-31, 2024. DOI: https://doi.org/10.14393/OBv8.e2024-23.

NÚÑEZ, I. B.; SILVA, S. D. R. O enfoque sistêmico dialético e a organização dos conteúdos da química: reflexões didático-filosóficas. *Revista Educação e Filosofia*. v. 33, n. 67, 2019. DOI: https://doi.org/10.14393/REVEDFIL.v33n67a2019-46410.

PEREIRA, L. F. *Estudo do pensamento sistêmico de Licenciandos em Química ao justificarem reações químicas: contribuições do sistema teórico de P. Ya. Galperin*. 240 p. Tese (Doutorado em Ensino de Ciências e Matemática) – Universidade Federal do Rio Grande do Norte, Natal, 2024.

RESHETOVA, Z. A. *Realización de los princípios del enfoque sistémico en las asignaturas*. Museo Politécnico. Editorial Conocimiento (Znanie), 1987.

RESHETOVA, Z. A. *Formação do Pensamento Sistêmico na Aprendizagem*. Livro Didático para Universidades. Moscou: Unity-Dana, 2002.

RESHETOVA, Z. A. The organization of the activity of learning and the student’s development. *Russian Education and Society*, v. 46, n. 9, p. 46-62, 2004. DOI: https://doi.org/10.1080/10609393.2004.11056909.

RESHETOVA, Z. A. Mind and activity. Psychic mechanism of learning. *National Psychological Journal*, v. 3, n. 27, p. 40-55, 2017. DOI: https://doi.org/10.11621/npj.2017.0306.

SÁLMINA, N. G. *La actividad cognoscitiva de los alumnos y el modo de estructurar la asignatura*. Moscou: Progreso, 1989.

SHRAGINA, L. I. Abordagens para o diagnóstico e desenvolvimento do pensamento sistêmico em escolares. *Metodologias para o desenvolvimento da inteligência*, v.1, n. 2, 2011.

TALÍZINA, N. F. Teoria da formação sistêmica das ações mentais hoje. *Questões de Psicologia*, n. 1, p. 92-101, 1993.

VYSOTSKAYA, E. V.; REKHTMAN, L. V. Two Approaches to Curriculum Design Following the Third Type of Orientation: Choosing 'Main Units' (with Chemistry Curriculum as a Example). *Cultural-Historical Psychology*, v. 8, n. 4, p. 42-54, 2012.

Recebido: abril/2026
Aprovado: maio/2026