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# Meaningful Learning Theory and its Critical Perspective: a theoretical framework for supporting research in Science Education

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**ABSTRACT**

Meaningful learning involves relating what is being received or discovered to concepts already present in an individual's cognitive structure, resulting in new ways of reasoning and potentially transforming how one feels, interacts with others, and acts upon the world. In this regard, studies focused on the development of meaningful and critical learning—an important goal in Science Education—require solid theoretical support. Therefore, this theoretical study, which is derived from a doctoral dissertation, aimed to bring together the main ideas of David Ausubel's Meaningful Learning Theory (1963) and its Critical Perspective, proposed by the Brazilian scholar Marco Antonio Moreira (2005), in order to support research in Science Education and related fields. To this end, the fundamental concepts, classifications, and processes that constitute these theories were compiled, and cognitive processes inherent to meaningful and critical learning were exemplified. The study contributes to Science Education by providing a theoretical framework that supports the organization of pedagogical practices committed to meaning-making, critical inquiry, and the articulation between scientific knowledge and the sociocultural context.

**KEYWORDS**: Critical Meaningful Learning. Teaching and Learning. Learning Theories.

## 1 INTRODUCTION

The social role of schools is to enable students to develop the knowledge, skills, and attitudes collectively constructed throughout history, allowing them to participate effectively in society. In this context, students do not merely adapt to reality; they also transform it by consciously applying what they have learned. Through learning, students acquire essential elements for participation and action in a society characterized by constant change. Therefore, the teaching process should foster the development of new representations, languages, and ways of perceiving the world based on the information acquired (Braga, 2019).

An educational inconsistency can be observed in Brazilian basic education, where children and young people are predominantly trained to take written examinations throughout their school years. Preparing students solely for tests and examinations does not, in itself, equate to educating them for life, since such assessments, although legitimate as diagnostic instruments, do not guarantee critical understanding or the meaningful acquisition of knowledge (Moreira, 2021a; Moreira, 2022). Considering these tests as feedback may be misleading, as they merely measure correct responses without providing assurance that knowledge has been genuinely learned and understood. Likewise, solving problems by applying the "correct formula" does not necessarily imply an understanding of the solution itself (Moreira, 2021a).

Within the context of Science Education, there is clear evidence of the predominance of a form of teaching that may be regarded as unscientific in contemporary educational practice (Wieman, 2013). This type of instruction often fails to emphasize fundamental aspects of the scientific method, such as observation, questioning, hypothesis formulation, and model construction. Moreover, it tends to be inflexible, with teachers presenting information as absolute truths, restricting the use of formulas and diagrams to simplified situations, and prioritizing the memorization of curricular content. Such an approach hinders students' ability to apply the knowledge they have constructed to new contexts (Vidmar; Sauerwein, 2021). Yet, it is precisely this capacity to reorganize and integrate learned knowledge when faced with new situations that is considered a desirable outcome in Science Education (Brasil, 2018; Oliveira, 2023; Oliveira; Cavalcante; Aquino, 2023). However, this process depends on the occurrence of meaningful learning, understood as the non-arbitrary and substantive incorporation of new knowledge into the student's cognitive structure (Ausubel, 2003).

Not everything that is taught is necessarily of interest to students, who select and prioritize the information they receive according to their willingness to learn. This natural learning process is essentially meaningful in nature. From the perspective of Meaningful Learning Theory (MLT) (Ausubel, 1963, 2003), meaningful learning involves relating new knowledge to the learner's prior conceptions and ideas, resulting in new ways of reasoning, feeling, and acting. Therefore, studies investigating meaningful learning and its implications are important for understanding this dynamic process and for providing theoretical support for research in education, particularly in Science Education.

In this context, the aim of this study was to bring together the main ideas of Meaningful Learning Theory and its Critical Perspective (Critical Meaningful Learning – CML) in order to support research in Science Education and related fields. By systematizing these approaches, this study seeks to expand the theoretical repertoire available to researchers and educators, contributing to more conscious and reflective pedagogical practices capable of promoting learning experiences that are meaningful to students in both their academic development and their preparation for citizenship.

## 2 MEANINFUL LEARNING THEORY

David Ausubel, an American psychiatrist and the son of Jewish immigrants to the United States, developed Meaningful Learning Theory (MLT) based on reflections arising from his own life experiences. His interest in understanding the learning process stemmed from the difficulties he encountered in American schools, which led to dissatisfaction with his own schooling. In his view, the conditions necessary to foster meaningful learning for himself and his peers—enabling them to substantively assimilate new knowledge—were virtually nonexistent (Masini, 2011). Through his professional practice and studies as a specialist in Developmental Psychology, Ausubel came to understand and appreciate the importance of the learner's idiosyncrasy, that is, the value of each individual's uniqueness in the process of constructing meanings (Ausubel, 1963; 2003; Masini, 2011).

Meaningful Learning Theory posits that meaningful learning occurs through a process of cognitive interaction between new knowledge, presented to students through different means, and relevant prior knowledge already available within their cognitive structure, referred to as subsumers. In this process, new information is not merely accumulated; rather, it is incorporated into the cognitive structure in a way that modifies both the newly learned knowledge and the subsumers that served as its anchoring points.

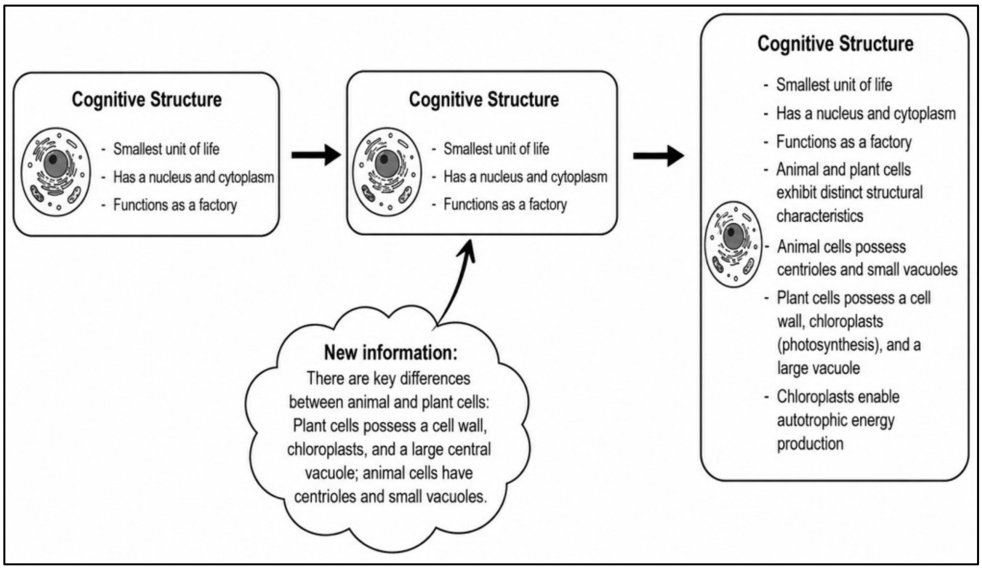
Thus, meaningful assimilation involves the reorganization, differentiation, and enrichment of existing meanings (Ausubel, 1963, 2003). This interaction must be both substantive and non-arbitrary. It is substantive because new knowledge is not assimilated literally, mechanically, or “word for word”; instead, it is re-elaborated by the learner according to their cognitive structure. It is non-arbitrary because this incorporation does not occur randomly, but through its relationship with specific, relevant, and conceptually appropriate subsumers associated with the content being learned (Ausubel, 2003; Moreira, 2012).

Ausubel (2003) defines cognitive structure as the individual's total and integrated body of knowledge. From the perspective of learning a particular subject, it refers to the content and organization of the ideas and conceptions that a student possesses within a specific area of knowledge. Therefore, cognitive structure is a construct unique to each individual, characterized by a high degree of organization, hierarchy, and interaction, and it develops in a singular manner throughout life (Ausubel, 2003; Moreira, 2012; Novak; Cañas, 2010).

Subsumers may consist of ideas, conceptions, symbols, mental representations, or propositions (Moreira, 2012). These pre-existing forms of knowledge within the student's cognitive structure constitute the most important variable in promoting meaningful learning (Ausubel, 1963, 2003). However, this variable is not always beneficial or constructive, as it may also function as an epistemological obstacle. Furthermore, identifying what students already know involves more than merely uncovering their prior knowledge; it also requires considering the student as a whole cultural and social subject, including their affective, bodily, and cognitive forms of expression and language (Lemos, 2011). “To this end, teachers must remain open to what students may reveal about their lived expectations, the objects incorporated into their lives, their existential conditions, and not solely their intellectual aspects” (Agra *et al*., 2019, p. 2).

It is important to note that learning becomes meaningful when new knowledge acquires significance for the student. This occurs, for example, when students are able to understand, describe, and interpret processes and situations using their own language; when they can interpret, argue, critique, reflect upon, and solve problems using the newly constructed knowledge; in short, when they achieve genuine understanding (Moreira, 2003). Figure 1 illustrates an example of meaningful interaction between prior knowledge and new knowledge presented to the student according to Meaningful Learning Theory.

Figure 1 – Representation of meaningful interaction, according to Meaningful Learning Theory, between a prior Biology concept (the subsumer *Cell*) and new information presented to the learner.



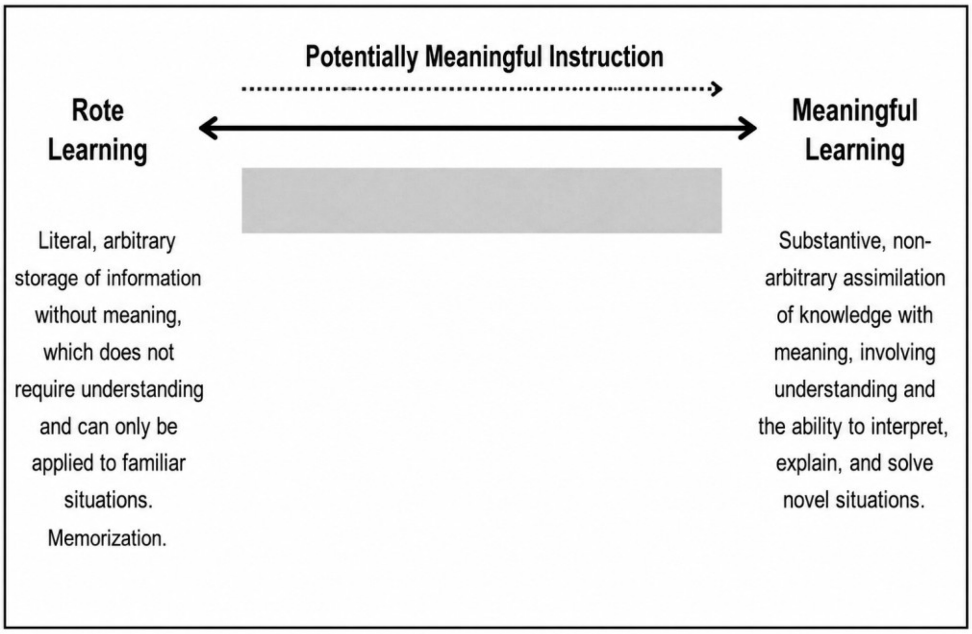

Source: The authors (2026).

Figure 1 depicts the cognitive structure of a student who is highly motivated to learn Cell Biology. In this structure, the subsumer *Cell* anchors three prior conceptions: the smallest unit of life, the presence of a nucleus, and the notion that the cell functions as a factory. After being presented with new information concerning the differences between animal and plant cells, and provided that the student considers this new concept relevant, a new meaning is established through the learning process. The student comes to understand that specific organelles, such as chloroplasts and the cell wall, distinguish different cell types and enable autotrophic energy production. This understanding requires a reorganization of the student's cognitive structure in order to integrate the new conception, which is perceived as both comprehensible and relevant—in other words, meaningful to the learner (Ausubel, 2003).

Meaningful Learning (ML) is established as a counterpoint to Rote Learning (RL), which consists of the memorization and acquisition of definitions, ideas, and concepts in a disconnected and arbitrary manner, without anchoring them to subsumers. However, Meaningful Learning and Rote Learning “should not be viewed as a dichotomy, but rather as a continuum in which they occupy opposite ends” (Moreira; Caballero; Rodríguez, 1997, p. 2). This continuum represents a progression from literal, arbitrary, and non-meaningful acquisition of knowledge to a substantive, non-arbitrary incorporation characterized by genuine understanding on the part of the learner (Figure 2) (Moreira, 2005).

The gray area shown in Figure 2 represents the transitional space between Rote Learning and Meaningful Learning. Within this zone, students may demonstrate “satisfactory performance” without actually understanding the content or topic being studied. This space is unstable and temporary, requiring active teacher mediation to guide learning toward the meaningful end of the continuum (Moreira, 2005).

Figure 2 – *Continuum* between Rote Learning and Meaningful Learning. Most learning processes occur within the gray zone.



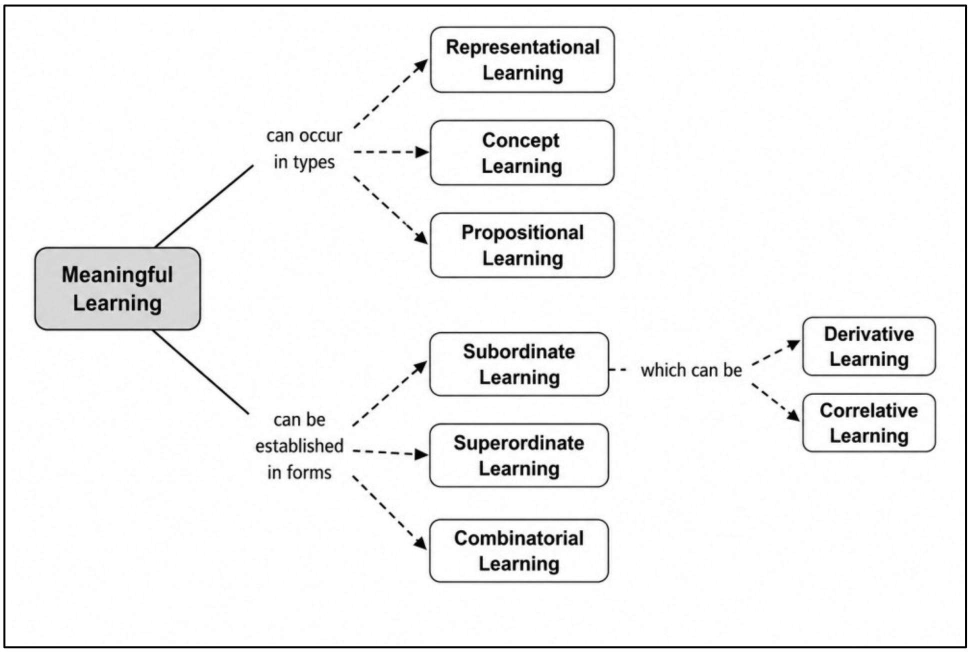

Source: Adapted from Moreira (2021c).

Another factor that has not yet been discussed, but is fundamental to the consolidation of meaningful learning, is the learner's predisposition to learn (Ausubel, 2003). For meaningful learning to occur, students must be willing to relate the meanings acquired from instructional materials to their cognitive structure in a non-arbitrary and substantive manner (Oliveira; Cavalcante; Aquino, 2023). This predisposition, however, should not be understood as something natural or spontaneous; rather, it is the result of a relationship constructed between the learner and knowledge, mediated by experiences that are meaningful and relevant to the individual. It is the teacher's responsibility to create conditions that foster openness to new knowledge by mobilizing prior knowledge, promoting dialogue, and connecting school content to students' lived experiences. Without such conditions, learning may remain at a rote level, even when the content itself is relevant (Moreira, 2005).

## 2.1 Types and Forms of Meaninful Learning

Figure 3 systematizes, in the form of a concept map, two fundamental dimensions of Meaningful Learning Theory (MLT): the types and forms through which meaningful learning may occur. This distinction is relevant because these categories do not refer to the same aspect of the learning process. Whereas the types concern the nature of the meaning constructed by the learner, the forms indicate how new knowledge relates to the subsumers available within the learner's cognitive structure. In this regard, Ausubel (2003) identifies three types of meaningful learning: representational, conceptual, and propositional. These differ according to the cognitive content involved and the degree of complexity of the meaning relationships established during the learning process.

Figure 3 – Types and Forms through Which Meaningful Learning Occurs.




Source: Oliveira (2023).

*Representational Meaningful Learning* occurs when a word, symbol, or other sign comes to represent particular objects, events, or situations for the learner, establishing “a one-to-one relationship between a symbol and an object or event” (Moreira, 2021c, p. 27). It is considered the most elementary type of meaningful learning because it corresponds to the initial attribution of meaning to signs, especially during vocabulary acquisition. Nevertheless, it should not be confused with rote learning, since it requires some prior knowledge capable of functioning as a subsumer, even if only in a rudimentary form (Ausubel, 2003). Although it is common during childhood, representational learning may occur at any age whenever individuals associate a term with specific examples or experiences without integrating it into a broader conceptual network. In Science Education, this may occur when a student understands biodiversity merely as “many animals and plants” observed in a particular environment, without relating it to genetic, species, and ecosystem diversity, nor to ecological interactions and conservation processes.

*Concept Learning* occurs when a linguistic sign ceases to designate only particular objects or events and comes to represent regularities, properties, or patterns shared across different situations (Ausubel, 2003; Moreira, 2021c). Unlike representational learning, it requires a greater degree of abstraction because it involves the construction or expansion of concepts capable of integrating new meanings into the learner's cognitive structure. Returning to the example of biodiversity, conceptual understanding implies recognizing that the term refers not merely to the presence of “many living organisms,” but to multiple dimensions of biological diversity, including species diversity, genetic diversity, functional diversity, and ecological diversity, encompassing variations among environments, communities, and ecosystems.

Within Concept Learning, Ausubel (2003) distinguishes two main processes: *concept formation and concept assimilation*. Concept formation occurs primarily during childhood, when children identify common characteristics across different situations through concrete and recurring experiences. For example, upon observing that a caterpillar feeds on leaves and that a bird may eat insects, a child begins to construct an initial notion of feeding relationships among living organisms. Concept assimilation, in turn, is more common during formal schooling and adulthood, when this initial notion is expanded through more systematic explanations. By studying a food chain, students come to understand that these relationships do not merely indicate “who eats whom,” but also involve the transfer of matter and energy among producers, consumers, and decomposers. Thus, learning a concept meaningfully does not consist of memorizing a definition; rather, it involves expanding and reorganizing meanings based on prior experiences and knowledge.

*Propositional Learning* occurs when students attribute meaning to complete statements, that is, to ideas expressed through propositions that articulate relationships among previously assimilated concepts. Unlike representational and concept learning, which involve more discrete or unitary meanings, propositional learning requires the integration of concepts into a more complex structure of meaning. For this reason, it presupposes the existence of representational and conceptual subsumers already available within the learner's cognitive structure, constituting a more advanced level of meaning construction (Ausubel, 2003).

Let us consider the proposition: “A reduction in biodiversity may compromise the ecological balance of an ecosystem.” To understand this proposition meaningfully, students must attribute meaning to its constituent terms, such as *biodiversity*, *ecological balance*, and *ecosystem*, while also understanding the relationship established among them. In this case, students do not merely recognize isolated words or concepts; rather, they construct an explanatory idea: the loss of biological diversity may affect the ecological relationships that sustain a given environment. Thus, propositional learning reflects a more complex level of meaning construction, in which representations and concepts are integrated into the understanding of a complete idea.

Within the scope of concept and propositional learning, Ausubel (2003) describes three forms through which meaningful learning may occur: *subordinate*, *superordinate*, and *combinatorial* learning. Each of these refers to the manner in which new meanings are incorporated into the learner's cognitive structure. *Subordinate Learning* occurs when new information is assimilated by anchoring it to a broader and more abstract concept already present in the individual's cognitive structure. This anchoring process is called *subsumption* and takes place when the subsumer possesses a higher degree of generality and can therefore integrate the new information in a non-arbitrary manner. “Because it is an interactive process, this anchoring is metaphorical, since the subsumer may be modified, acquire new meanings, become more differentiated, and become more capable of ‘anchoring’ or subsuming other new knowledge” (Moreira, 2021c, p. 28).

*Subordinate Meaningful Learning* may occur in either a *derivative* or a *correlative* form. Derivative subordinate learning takes place when new information confirms, reinforces, or exemplifies an existing subsumer. Correlative subordinate learning, in contrast, occurs when the new information expands, modifies, or further elaborates that subsumer (Ausubel, 2003). In Science Education, derivative subordinate learning may occur when a student, already understanding that symptoms are observable manifestations of changes in the body, learns that fever is an example of a symptom associated with infectious processes. Correlative subordinate learning, on the other hand, may occur when the student's understanding of fever is expanded through learning that fever is not merely a sign of illness, but a physiological response regulated by the body, associated with inflammation and thermal regulation by the hypothalamus. Thus, whereas the first situation specifies and reinforces a more general idea, the second modifies and increases the complexity of the initial subsumer.

*Superordinate Meaningful Learning* occurs when new information is more inclusive, abstract, and comprehensive than the knowledge already present in the learner's cognitive structure. In this case, the new idea is not simply anchored to a previously available, more general subsumer; rather, it comes to function as a new subsumer, reorganizing and integrating previously acquired knowledge, which is then understood from a broader perspective (Ausubel, 2003). Although this form of learning is less common than subordinate learning, it plays an essential role in the construction of more inclusive concepts and in the integration of propositions that may initially appear disconnected or even contradictory (Ausubel, 2003; Moreira; Caballero; Rodríguez, 1997).

In this sense, Superordinate Meaningful Learning represents a cognitive process that requires a greater degree of abstraction and contributes significantly to the expansion of the learner's conceptual structure. An example of superordinate learning in Science Education occurs when, upon understanding the concept of an *ecosystem* as a dynamic system involving interacting biotic and abiotic factors, students reorganize previously acquired knowledge that had been treated more independently, such as *flora*, *fauna*, and *climate*, integrating them into a broader and more coherent conceptual framework.

Combinatorial Meaningful Learning occurs when new information does not fit directly into specific subsumers already present in the learner's cognitive structure, as is the case with subordinate or superordinate learning, yet still relates meaningfully to a broader set of prior knowledge (Ausubel, 2003). Rather than being anchored to a single concept or to a direct hierarchical relationship, the new content establishes broader, lateral, and non-linear connections with relevant ideas already available regarding the topic under study (Aquino; De Chiaro, 2013; Moreira, 2021c). This form of learning is common in the assimilation of generalizations, analogies, and correlations among distinct concepts, and it is particularly important in situations that require the integration of different fields of knowledge.

An example of combinatorial meaningful learning occurs when, while studying the acidification of water bodies caused by atmospheric pollutants, students relate prior knowledge about acids, pH, oxides, chemical reactions, the water cycle, air pollution, and impacts on aquatic organisms. In this case, the new information is not supported by a single specific subsumer, but rather by a network of interconnected ideas that, when articulated together, enable the understanding of an environmental issue in its chemical, ecological, and social complexity.

**2.2 Processes Inherent to Meaningful Learning**

The cognitive structure is organized, dynamic, and constantly evolving. Meaningful learning is therefore a progressive process in which previously established knowledge interacts both with itself and with new information that is received or discovered (Moreira, 2012). Within this process, two cognitive mechanisms are fundamental to the establishment of meaningful learning: *progressive differentiation and integrative reconciliation* (Ausubel, 2003).

As previously discussed, in the most common form of meaningful learning—*subordinate learning*—the subsumers present in the learner's cognitive structure interact with new information, serving as the foundation for the construction of new meanings. As this process unfolds, the subsumer itself is transformed: it becomes more elaborate, more differentiated, and more capable of anchoring future knowledge. This process of conceptual refinement is referred to as *Progressive Differentiation* (PD) (Ausubel, 2003; Moreira, 2005). Progressive Differentiation is a process through which knowledge is hierarchically organized in increasing levels of complexity, progressing from more general and inclusive concepts to more specific ones. In other words, during PD, “more comprehensive concepts are successively broken down into more specific concepts” (Bolacha; Amador, 2003, p. 33). In Science Education, this process can be observed, for example, when a student who already understands the general concept of the *respiratory system* further differentiates this knowledge by learning the specific functions of structures such as the *alveoli*, *diaphragm*, and *bronchioles*. Progressive Differentiation enables the original concept to become more refined and functional for future learning.

Regarding the dynamics involved in Progressive Differentiation, Moreira (2021b) explains that, as new knowledge is meaningfully assimilated, it interacts with prior knowledge and gradually becomes differentiated from it, acquiring greater specificity and complexity. However, if this process were to occur continuously and in isolation within a particular domain of knowledge, it could lead to the compartmentalization of knowledge, resulting in a situation in which “nothing would be connected to anything else” (Moreira, 2021b).

It is precisely to prevent such isolation that a second cognitive process operates in a complementary manner: Integrative Reconciliation (IR). During meaningful learning, the cognitive structure undergoes reorganizations that enable learners to identify similarities, distinguish particularities, establish conceptual relationships, and integrate examples. In other words, beyond differentiation, it is also necessary to reconcile and integrate the meanings that have been constructed (Ausubel, 2003; Moreira, 2021c). Integrative Reconciliation functions by eliminating contradictions, resolving inconsistencies, and promoting the integration of concepts through hierarchical reorganizations and the superordination of ideas (Moreira, 2012). A didactic example of Integrative Reconciliation in Science Education occurs when a student who has learned the concepts of *alcoholic fermentation and lactic fermentation* separately comes to understand them as variations of the same anaerobic biochemical process, identifying common patterns and reorganizing the meanings associated with the concept of *metabolism*.

When meaningful learning occurs, it is crucial to progressively differentiate the meanings of newly acquired knowledge in order to discern its nuances and specific characteristics. At the same time, it is necessary to promote an integrative reconciliation capable of connecting these meanings with those already present in the learner's cognitive structure. An exclusive emphasis on differentiation may lead learners to perceive knowledge as isolated compartments; conversely, continuous integration without refinement may result in an excessively homogeneous perception in which everything appears to be the same. Both processes are essential to cognitive construction and operate with varying degrees of intensity throughout the learning process. Progressive Differentiation tends to occur more frequently, particularly in subordinate learning, whereas Integrative Reconciliation, although less common, is fundamental in broader cognitive reorganizations, such as those observed in superordinate and combinatorial learning (Moreira, 2012).

Meaningful learning involves processes that lead to the construction of meanings based on prior knowledge, promoting a deep understanding of the content. However, this does not imply that the knowledge constructed will be retained permanently. Following the establishment of meaningful learning, a retention phase occurs, followed by a gradual and natural loss of dissociability between newly acquired knowledge and the subsumers that anchored it. This phenomenon is known as *obliterative assimilation* (Ausubel, 2003) and is considered analogous to forgetting within the framework of Meaningful Learning Theory (Moreira, 2007). Obliterative assimilation refers to the progressive fusion of assimilated meanings with the meanings that originally served as their foundation, to the point that they become virtually indistinguishable from one another, while still maintaining cognitive functionality (Moreira, 2012). For example, a student who has meaningfully learned the concept of *epithelial tissue* may, after several years without revisiting the content, no longer remember the exact names of its layers. Nevertheless, the student may retain an organized intuition regarding its function and location, demonstrating that the learning occurred meaningfully and remained integrated within the cognitive structure.

Thus, unlike Rote Learning, in which forgetting tends to be rapid and nearly complete, in Meaningful Learning forgetting is residual. In other words, a conceptual trace remains within the subsumer that interacted with the new knowledge, even when the content itself is no longer immediately retrievable (Ausubel, 2003; Moreira, 2021c). When knowledge has not been used for a long period of time but was originally learned meaningfully, individuals often experience a positive and reassuring sense that they will be able to relearn it relatively easily and in less time than was initially required. In contrast, when learning has occurred through rote memorization, individuals are more likely to experience a negative perception—that the content was never truly learned in the first place—making the notion of relearning seem incoherent (Moreira, 2012).

Furthermore, the advantages of Meaningful Learning over Rote Learning are not limited to retention or the capacity for relearning. Meaningful Learning involves the active construction of meanings, accompanied by understanding and the ability to apply acquired knowledge in new contexts. In Rote Learning, by contrast, the learner's performance tends to be restricted to familiar or repetitive situations. In summary, Meaningful Learning not only promotes greater durability of knowledge but also enables faster and more robust relearning, unlike Rote Learning, in which this possibility is virtually nonexistent (Ausubel, 2003; Moreira, 2012, 2021c).

### 2.3 Programmatic Principles for Meaningful Learning

To facilitate Meaningful Learning in educational settings, it is important for teachers to consider two fundamental aspects: (a) the conceptual structure of the curricular content and (b) the learner's cognitive structure. Regarding the first aspect, Moreira, Caballero, and Rodríguez (1997) emphasize the need for a rigorous conceptual analysis of the content in order to identify the central concepts, ideas, and procedures that organize a given field of knowledge. Such analysis makes it possible to distinguish what is structurally essential from what is merely accessory, thereby guiding pedagogical planning toward elements with greater potential for anchoring, differentiation, and conceptual integration. Thus, avoiding the overload of irrelevant information does not mean impoverishing the content; rather, it involves selecting and organizing those elements that are most likely to promote substantive and non-arbitrary relationships between new knowledge and the learner's cognitive structure.

In this regard, it is necessary to critically analyze curricular materials and educational programs, since not everything they contain needs to be taught (Moreira; Caballero; Rodríguez, 1997). The sequence in which concepts and ideas are presented in textbooks and curricula does not always facilitate the establishment of meaningful connections with students' prior knowledge. Therefore, reorganizing and adapting instruction based on such analysis constitutes an essential pedagogical practice, particularly when the goal is to promote substantive and non-arbitrary relationships between new knowledge and the learner's cognitive structure.

With regard to the second aspect, the presence of specific and relevant subsumers capable of interacting with new knowledge is an indispensable condition for Meaningful Learning (Ausubel, 2003). When such subsumers are unavailable, insufficiently differentiated, or not sufficiently clear to the learner, Ausubel recommends the use of advance organizers. These instructional resources serve to establish a cognitive bridge between what the learner already knows—even if only in a limited way—and the new content that has the potential to be learned meaningfully (Ausubel; Novak; Hanesian, 1980).

Regarding advance organizers, Moreira (2012) explains that they are introductory resources presented before the learning material, at a higher level of generality, inclusiveness, and abstraction than the content to be taught. Unlike summaries or outlines, which typically operate at the same level of abstraction as the content itself, advance organizers function as cognitive and conceptual bridges between what students already know and the new knowledge they are expected to learn. They may take different forms, such as a problem situation, a guiding question, an introductory reading, an experiment, a demonstration, a film excerpt, or even an introductory lesson, provided that they fulfill the function of conceptually preparing learners for the new content. The essential requirement is that they precede systematic contact with the learning material and enhance the possibilities for meaningful anchoring.

With regard to facilitating Meaningful Learning through the organization of instructional activities, Ausubel (2003) identifies four *programmatic principles* related to content organization: *Progressive Differentiation, Integrative Reconciliation, Consolidation, and Sequential Organization*. Progressive Differentiation and Integrative Reconciliation function both as cognitive processes and as pedagogical guidelines that should be considered when promoting Meaningful Learning (Moreira; Caballero; Rodríguez, 1997; Moreira, 2012).

*Progressive Differentiation* should constitute the first instructional movement. In the organization of teaching materials, this principle implies presenting the concepts and ideas of the content gradually, progressing from the most general and inclusive aspects to the more specific and detailed ones. For example, when addressing the topic of *reproduction* in Science Education, teachers may begin with the general idea of the continuity of life, then proceed to reproductive modes (asexual and sexual reproduction), the systems involved, and only subsequently address anatomical and physiological aspects.

Following this differentiation, *Integrative Reconciliation* should be promoted. That is, instructional actions should enable students to identify relationships, recognize meaningful similarities and differences among concepts, and resolve real or apparent inconsistencies (Ausubel, 2003; Moreira; Caballero; Rodríguez, 1997). In the previous example, such reconciliation may occur when students come to understand that fertilization, although manifested in different ways among organisms that reproduce sexually, constitutes a common process involving the union of gametes. This understanding makes it possible to comprehend the diversity of reproductive processes within a more coherent and integrated conceptual framework.

Ausubel defines these first two programmatic principles on the basis of the very processes that characterize the dynamics of cognitive structure. In other words, when organizing new knowledge, learners must progressively differentiate the meanings they acquire and integratively reconcile them with preexisting ideas, thereby avoiding fragmentation, overlap, or conceptual contradictions. Consequently, instruction becomes potentially meaningful when these dynamics are considered guiding principles of pedagogical action, organizing content in ways that foster both the differentiation of concepts and the integration among them (Moreira, 2012).

The principle of *Consolidation*, in turn, involves ensuring that learners have achieved sufficient clarity, stability, and availability of the knowledge addressed before progressing to new content that depends upon it. This is essential for promoting the existence of specific and relevant subsumers that can support future learning (Ausubel, 2003). Consolidation may be fostered, for example, through the collaborative construction of concept maps at the end of a thematic unit, allowing students to reorganize meanings in their own words, make connections explicit, review their understandings, and identify possible conceptual gaps.

Finally, *Sequential Organization* consists of arranging content in a logical and interconnected manner, taking into account conceptual hierarchy, the degree of inclusiveness of ideas, and the dependency relationships among topics (Ausubel, 2003; Moreira, 2005). In Science Education, this may involve organizing instruction so that more general concepts, such as ecosystems and energy flow, provide the foundation for understanding more specific concepts, such as food chains, food webs, and ecological pyramids. Thus, sequence should not be understood as a rigid order, but rather as an intentional organization that promotes Progressive Differentiation, conceptual integration, and the increasing complexity of meanings.

## 3 CRITICAL MEANINFUL LEARNING

Following David Ausubel's retirement, Meaningful Learning Theory (MLT) was further developed and disseminated by Joseph Novak, a professor at Cornell University. Novak not only systematized the foundations of the theory but also conducted important empirical research aimed at its application in education. It was within this context that he supervised the doctoral studies of Marco Antonio Moreira, a physicist and prominent Brazilian scholar in the field of Science Education (Oliveira, 2023).

At a certain point in his academic career, Moreira encountered the provocative book *Teaching as a Subversive Activity* (Postman; Weingartner, 1969, as cited *in* Moreira, 2005). The work highlighted the limitations of traditional teaching, arguing that concepts should not be presented as absolute truths, immutable certainties, entities detached from their contexts, outcomes of simplistic cause-and-effect relationships, or reductive dichotomies. Furthermore, it criticized the “vertical transmission of knowledge” and advocated for more dialogical and emancipatory pedagogical practices (Moreira, 2005).

While Postman and Weingartner (1969, as cited in Moreira, 2005) focused on disruptive pedagogical experiences, Moreira directed his attention toward the learning process itself, reinterpreting Meaningful Learning Theory through the lens of the learner's own subversive stance. For him, learning meaningfully involves more than constructing meanings in a logical and substantive manner; it entails critically appropriating knowledge, questioning it, reconstructing it, and mobilizing it in the transformation of both oneself and reality. Consequently, he came to conceive meaningful learning as a pathway toward the development of a critical and active stance in relation to the contemporary world (Moreira, 2005, 2017).

It is within this intellectual horizon that, in the early 2000s, Moreira proposed the Critical Meaningful Learning (CML) Perspective: an epistemological and ethical expansion of Meaningful Learning Theory that repositions it in light of the social, political, environmental, and cultural challenges of our time. Although he acknowledges the validity of Ausubel's original proposal for education, Moreira argues that meaningful learning must be redefined through a critical dimension. This implies understanding that learning meaningfully is not limited to attributing meaning to new knowledge; it also involves the capacity to problematize legitimized discourses, reconstruct representations of the world, and act more consciously in the face of the contradictions of reality (Moreira, 2005; Oliveira, 2023; Oliveira; Cavalcante; Aquino, 2023).

Moreira (2005) recognizes that teaching may be potentially meaningful and yet still be alienating if content and themes are addressed in an authoritarian manner, without room for dialogue, problematization, or the collective construction of meanings. In this context, Critical Meaningful Learning proposes a departure from the centrality of "transmission" and an openness to learning processes that embrace multiple voices, meanings, and contexts. As the author argues, meaningful learning "must cease to be merely meaningful and evolve into being also critical, committed to the transformation of both the school and reality itself." Accordingly, Critical Meaningful Learning may be understood as a *theoretical-pedagogical perspective according to which learning meaningfully does not consist solely of relating new knowledge to cognitive structure in a substantive and non-arbitrary manner. It also involves developing the intellectual, ethical, and social conditions necessary to question, contextualize, and reconstruct such knowledge in light of the concrete problems of reality.*

From this perspective, students are not conceived as mere recipients of culturally legitimized meanings, but as individuals capable of critically appropriating them, recognizing their limitations, critically examining their implications, and using them to interpret and transform the world in which they live. In this way, Critical Meaningful Learning (CML) articulates the cognitive construction of meanings with the critical development of the individual, going beyond active methodologies or pedagogical approaches that are limited to student participation. Its distinctive feature lies in the assertion that knowledge is not neutral, that learning should not be reduced to the student's adaptation to content, and that every meaningful educational process must include questioning the very foundations, uses, and social consequences of what is learned (Moreira, 2005; Oliveira, 2023; Oliveira; Cavalcante; Aquino, 2023).

To facilitate the development of Critical Meaningful Learning, and analogously to the programmatic principles of Meaningful Learning, Moreira (2005) and Chirone, Moreira, and Sahelices (2021) propose a set of facilitating principles to guide the planning of instructional actions with the potential to promote CML (Chart 1). These principles do not replace the foundations of Meaningful Learning Theory; rather, they function as didactic and epistemological indicators for fostering a more critical, contextualized, and meaningful form of learning.

Chart 1 – Guiding principles for Critical Meaning Learning

| **Principle** | **Categorization** |
|---|---|
| *1. Prior Knowledge Principle* | Learning occurs based on what one already knows. Since prior knowledge is the most important variable for meaningful learning, there is no sense in developing criticality without first achieving meaningful learning. |
| *2. Social Interaction and Questioning Principle* | Teaching should be centered on the negotiation of meanings between teacher and student, emphasizing the exchange of questions rather than merely providing ready-made answers. |

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| *3. Non-centrality of the Textbook Principle* | Teaching should not rely exclusively on a textbook, workbook, or instructional manual. Otherwise, what occurs is training rather than a meaningful teaching-learning episode. It is important to make explicit the concepts and ideas accepted within the subject matter from different perspectives, using diverse resources and authors. |
| *4. Learner as Perceiver Principle* | This principle highlights the importance of observing how information is perceived and represented by students in light of their prior conceptions. |
| *5. Knowledge as Language Principle* | Learning content meaningfully is to learn its language. Criticality emerges when students perceive this language as a new way of understanding and interpreting the world. |
| *6. Semantic Awareness Principle* | Recognizing that the meaning of words is determined by people rather than being intrinsic to the words themselves implies understanding that the meanings attributed to them are shaped by each individual's personal experience. |
| *7. Learning through Error Principle* | Making mistakes is a natural part of learning. Scientific knowledge itself develops through the refutation of incorrect theories. Errors provide opportunities for improvement and for identifying other inconsistencies. Students should be encouraged to seek, identify, and work with errors as a means of learning, since systematically searching for mistakes is an exercise in critical thinking. |
| *8. Unlearning Principle* | Students should be encouraged to unlearn, in the sense of abandoning knowledge that may be hindering the meaningful learning of new concepts. Learning to unlearn enables students to distinguish relevant subsumers from irrelevant ones. Facilitating this process should be one of the school's missions in contemporary society. |
| *9. Uncertainty of Knowledge Principle* | Knowledge is uncertain because it consists of responses to the questions asked and to the definitions and metaphors employed. Questions are instruments of perception, while definitions and metaphors are instruments of thought. Knowledge would change if the questions, definitions, and metaphors upon which it is based also changed. |
| *10. Active Student Participation and Diversity of Teaching Strategies Principle* | Just as educational materials should be varied, teaching strategies should also be diverse. Teachers should move beyond exclusive reliance on the blackboard or purely expository presentations and encourage students to actively construct knowledge through different methods. Repeated use of the same strategy may render teaching discouraging and monotonous, failing to promote students' criticality. |
| *11. Narrative Abandonment Principle* | Simply repeating what the teacher says or presents does not promote understanding, nor does it foster criticality. Teaching should focus on students, promoting actions that enable them to externalize and negotiate the meanings they construct. |
| *12. Overcoming Difficulties Principle* | Critically meaningful learning also involves facing and overcoming cognitive and emotional difficulties through the mediation of others and/or with the support of appropriate educational |

| | |
|---|---|
| | materials. Overcoming challenges is an active part of the process of constructing meanings with critical awareness. |
| *13. Feedback Principle* | This principle emphasizes the value of feedback within the teaching-learning process. Through feedback, teachers provide guidance that expands, deepens, or reorganizes the meanings constructed by students, fostering continuity, reflection, and criticality in learning. |

Source: Adapted from Moreira (2005) and Chirone, Moreira e Sahelices (2021).

When addressing electrical energy, teachers may encourage students to understand concepts such as power, energy consumption, voltage, electric current, and energy transformation, while relating them to the social, economic, and environmental impacts of electricity use. To do so, instruction may begin with students' prior knowledge regarding electricity bills, household appliances, power outages, energy waste, and renewable energy sources, avoiding the restriction of learning to the mechanical application of formulas. Such an approach may involve analyzing electricity bills, comparing the energy consumption of different devices, and discussing the energy matrix. Thus, when studying electric power, students not only understand its physical foundations but also examine issues such as inequality in access to energy, environmental impacts, responsible consumption, and the economic interests involved in the production and distribution of this resource. In this way, learning becomes both meaningful and critical because students do not merely learn physical concepts; they use them to interpret and critically examine reality.

Critical Meaningful Learning does not propose replacing Meaningful Learning Theory, but rather critically expanding its assumptions through ethical and political commitments to education and to the formation of more conscious, sensitive, and transformative individuals. It is an approach that recognizes the importance of constructing meanings anchored in subsumers while also requiring the exercise of doubt, critique, and action (Moreira, 2005). In times marked by misinformation, denialism, and socio-environmental crises, Critical Meaningful Learning emerges as a theoretical and pedagogical alternative capable of addressing the complexity of human development within Science Education (Oliveira, 2023; Oliveira; Cavalcante; Aquino, 2023).

However, Critical Meaningful Learning can hardly be achieved without a flexible curriculum, a dialogical school environment, and assessment practices consistent with its principles. Even when teachers seek to promote critical learning, the rigidity of educational systems, pressure for immediate results, and standardized assessment models often redirect instruction toward mechanical reproduction of knowledge. As a result, learning may at times be meaningful, yet it will rarely be critical in the sense proposed by Moreira (2005), which requires learners to mobilize knowledge in order to interpret, question, and transform reality.

For this reason, Critical Meaningful Learning should not be understood as an isolated instructional technique, but rather as a pedagogical commitment that permeates content selection, attention to students' perspectives, the choice of educational materials, teaching strategies, and assessment practices. It is a perspective that articulates conceptual rigor, dialogue, and ethical-political commitment, recognizing knowledge as a situated construction shaped by symbolic, social, and cultural disputes. In this way, Science Education moves beyond merely teaching concepts about the world and begins to create conditions under which teachers and students can reinterpret knowledge, reality, and themselves in the pursuit of a more just, critical, and supportive society.

## 4 FINAL CONSIDERATIONS

This article brought together the main ideas of Meaningful Learning Theory (MLT) and Critical Meaningful Learning (CML), seeking to contribute to the field of Science Education and related areas. The text presented the central concepts of these approaches, discussed their underlying processes and programmatic principles, and highlighted the foundations that support learning characterized by greater meaning and awareness. Meaningful Learning Theory provides a consistent framework for understanding how learning can occur meaningfully, provided that new information is integrated into the learner's cognitive structure. Its principles offer important guidance for designing educational proposals that respect what students already know, organizing content in ways that foster substantive and enduring relationships among concepts.

However, learning meaningfully does not necessarily imply learning critically. It is possible to understand concepts and ideas without questioning their implications or reflecting on the contexts in which they were produced. It is precisely this gap that Critical Meaningful Learning seeks to address. By expanding the foundations of Meaningful Learning Theory, CML incorporates an ethical, social, and epistemic dimension that encourages learners to construct their own meanings, reconstruct understandings, and take a position in relation to knowledge.

By recognizing that school knowledge is not neutral and that learning should involve dialogue, problematization, and openness to new possibilities, Critical Meaningful Learning proposes that the learning process should also be a process of becoming more conscious and more sensitive to the transformations of the world. This approach requires teachers not only to organize content carefully, but also to pay close attention to the meanings that such content may evoke and to the experiences it may trigger.

Far from constituting a forced overlap, the articulation between Meaningful Learning Theory (MLT) and Critical Meaningful Learning (CML) represents a concrete and powerful possibility for Science Education. Through this articulation, it becomes possible to envision pedagogical practices that combine conceptual clarity with critical openness, that respect students' prior knowledge while also challenging them to reflect, question, and construct new meanings for what they learn.

This study brings together and discusses the perspectives of MLT and CML in order to provide a theoretical foundation for teachers, researchers, and teacher educators committed to an approach to education that goes beyond the mere “transmission of content.” It is a proposal that understands the classroom as a space for meaning-making, dialogue, and transformation. In this context, teaching science also means teaching learners to think, question, reconstruct, and act. It is hoped that this manuscript will inspire more conscious, engaged, and socially committed pedagogical practices, fostering the development of individuals capable of learning deeply and, above all, of transforming the world through what they learn.

# TEORIA DA APRENDIZAGEM SIGNIFICATIVA E SUA PERSPECTIVA CRÍTICA: CONSTRUCTO TEÓRICO PARA SUBSIDIAR PESQUISAS NO ENSINO DE CIÊNCIAS

**RESUMO**

Aprender significativamente envolve associar aquilo que está sendo recebido ou descoberto com as concepções que já estão presentes na estrutura cognitiva do indivíduo, resultando em novas formas de raciocinar e podendo modificar a maneira como ele se sente, interage com os outros e age perante o mundo que o cerca. Neste sentido, é importante que estudos que se debrucem sobre o desenvolvimento de aprendizagens significativas e críticas, que é algo desejado no Ensino de Ciências, sejam subsidiados. Posto isto, o presente estudo teórico, que é um recorte de uma tese de doutorado, objetivou reunir as principais ideias da Teoria da Aprendizagem Significativa de David Ausubel (1963) e sua Perspectiva Crítica, proposta pelo professor brasileiro Marco Antonio Moreira (2005), a fim de subsidiar estudos no Ensino de Ciências e áreas afins. Dessa forma, foram reunidos os conceitos, classificações e processos fundamentais que constituem essas teorias, além de exemplificados movimentos cognitivos inerentes ao processo de aprendizagem significativa e crítica, subsidiando o Ensino de Ciências ao fornecer um referencial teórico que fundamenta a organização de práticas pedagógicas comprometidas com a construção de significados, a problematização crítica e a articulação entre conhecimento científico e contexto sociocultural.

**PALAVRAS-CHAVE:** Aprendizagem Significativa Crítica. Ensino-Aprendizagem. Teorias de Aprendizagem.

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