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What Does Learning Science Mean to K-12 Students?

O Que Significa Aprender Ciências para Estudantes da Educação Básica?
¿Qué Significa Aprender Ciencias en la Educación Primaria y Secundaria?

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Abstract

We investigated how Brazilian K-12 students define and recognize their learning in Natural Sciences, where they locate this process, and what conditions foster it. We conducted a qualitative study inspired by phenomenography, using an open-ended questionnaire administered to 56 students from one public school in the state education system of Goiás, Brazil, enrolled in the final years of elementary school and in high school; the responses were analyzed using content analysis. Hybrid conceptions emerged: while learning is often seen as content mastery, there are signs of an investigative framework focused on explaining phenomena with evidence and connecting concepts. The main criteria for "knowing they have learned" include explaining in their own words, transferring knowledge to new situations, and justifying answers. Learning is described as distributed across the classroom, hands-on activities, and independent study; rereading is frequent, whereas active strategies are less common. Key facilitators were clear explanations, well-organized content, and opportunities for questioning, while obstacles included noise, classroom disruption, fatigue, and fast-paced instruction. A gap was also identified between the value ascribed to the subject and its application in daily life. We conclude that reducing the mismatch between what students recognize as learning and what they actually practice requires making quality criteria explicit and implementing investigative routines with review and error analysis.

Keywords: Natural Sciences, Conceptions of Learning, Self-Regulation, Inquiry-Based Teaching, K-12 Education, BNCC

Resumo

Investigamos como estudantes da educação básica brasileira definem e reconhecem sua aprendizagem em Ciências da Natureza, em que espaços a situam e quais condições a favorecem. Conduzimos um estudo qualitativo, de inspiração fenomenográfica, com questionário aberto aplicado a 56 estudantes de uma escola pública da rede estadual de Goiás, nos anos finais do ensino fundamental e no ensino médio; as respostas foram submetidas à análise de conteúdo. Emergiram concepções híbridas: prevalece a ideia de aprender como domínio de conteúdos, ao mesmo tempo, surgem indícios de uma moldura investigativa centrada em explicar fenômenos com evidências e articular conceitos. Entre os critérios de "saber que aprendeu", destacam-se explicar com palavras próprias, transferir para novas situações e justificar respostas. A aprendizagem é descrita como distribuída entre sala de aula, atividades práticas e estudo autônomo; observa-se forte presença de releitura e menor uso de estratégias ativas. Os principais facilitadores foram a explicação clara, a organização do conteúdo e o espaço para dúvidas; os obstáculos incluíram barulho, indisciplina, cansaço e ritmo acelerado. Identificou-se ainda uma lacuna entre o valor atribuído à disciplina e sua aplicação no cotidiano. Concluímos que reduzir o descompasso entre o que os estudantes reconhecem como aprender e o que praticam requer explicitar critérios de qualidade e instituir rotinas de investigação com retomadas e análise de erros.

Palavras-chave: Ciências da Natureza, Concepções de Aprendizagem, Autorregulação, Ensino por Investigação, Educação Básica, BNCC

Resumen

Investigamos cómo los estudiantes de la educación básica brasileña definen y reconocen su aprendizaje en Ciencias de la Naturaleza, en qué espacios lo sitúan y qué condiciones lo favorecen. Realizamos un estudio cualitativo, con inspiración fenomenográfica, mediante un cuestionario abierto aplicado a 56 estudiantes de una escuela pública de la red estatal de Goiás, Brasil, matriculados en los últimos años de la educación primaria y en la educación secundaria; las respuestas fueron sometidas a análisis de contenido. Surgieron concepciones híbridas: aunque predomina la idea de aprender como dominio de contenidos, se observan indicios de un marco investigativo centrado en explicar fenómenos con evidencias y articular conceptos. Entre los criterios de "saber que aprendió", destacan explicar con palabras propias, transferir el conocimiento a nuevas situaciones y justificar respuestas. El aprendizaje se describe como distribuido entre el aula, las actividades prácticas y el estudio autónomo; la relectura es frecuente, mientras que las estrategias activas son menos comunes. Los principales facilitadores fueron la explicación clara, la organización del contenido y el espacio para dudas, mientras que los obstáculos incluyeron ruido, indisciplina, cansancio y ritmo acelerado. También se identificó una brecha entre el valor asignado a la asignatura y su aplicación en la vida cotidiana. Concluimos que reducir el desajuste entre lo que los estudiantes reconocen como aprendizaje y lo que practican requiere explicitar criterios de calidad e instaurar rutinas de investigación con revisiones y análisis de errores.

Palabras clave: Ciencias de la Naturaleza, Concepciones del Aprendizaje, Autorregulación, Enseñanza por Investigación, Educación Básica, BNCC

Introduction

Learning in K-12 education is not limited to accumulating content. It involves understanding what students regard as learning, which forms of effort they consider legitimate as study, and why they believe learning is worthwhile (Biggs & Tang, 2011; Pozo & Crespo, 2021). Within this framework, Vermunt and Vermetten (2004) conceptualize learning as an integrated process that articulates four components: processing strategies, regulation strategies, conceptions of learning, and learning orientations. These elements form relatively stable profiles that influence learning outcomes and experiences.

From this perspective, the quality of learning depends on the alignment between students' self-regulation and the external regulation provided by instruction. When there is congruence between task demands and instructional support, including expectations regarding how students are expected to study, engagement and persistence tend to increase, especially in the final years of K-12 education, a stage marked by greater performance pressure and the definition of educational trajectories (Santos & Mortimer, 2000).

In the domain of Natural Sciences, learning retains general dimensions of learning, such as assigning meaning, regulating one's own study, and using knowledge in new situations. However, it also acquires specificity because it is oriented toward the construction and revision of explanations about natural phenomena through evidence, models, specialized language, and investigative practices. Learning science involves articulating different ways of understanding natural phenomena and, therefore, engaging with processes of conceptual change in which everyday, school-based, and scientific conceptions coexist and interact. Mortimer et al. (2014) propose that concepts are not single entities but rather sets of zones of meaning activated according to context, language, and the purpose of the activity. From this perspective, conceptual change does not imply replacing prior ideas with scientific conceptions, but rather reconfiguring the conceptual profile by expanding the use of zones closer to scientific thinking without eliminating those that give meaning to everyday experience.

By articulating learning profiles and conceptual profiles, it becomes possible to observe that beliefs and learning strategies form patterns shaped by school routines. These patterns help explain why ways of learning science tend to reflect broader modes of learning, that is, forms of coherence between general cognitive habits and domain-specific ways of constructing scientific knowledge (Tsai & Kuo, 2008). In this context, teachers' planning and discursive interventions can create conditions for shifts between zones of meaning, favoring the expansion of the conceptual profile in line with the balance between students' self-regulation and the external regulation of instruction (Vermunt & Vermetten, 2004).

The literature shows that conceptions of learning tend to shape approaches to studying. Many students describe learning as memorization and preparation for tests, whereas others associate it with understanding and explaining ideas in their own words, a distinction that reflects surface and deep approaches to learning (Freire, 2009; Freire & Gustavo, 2006; Gomes, 2011; Tsai & Kuo, 2008; Tytler & Hubber, 2016). These conceptions articulate cognitive, epistemological, and motivational dimensions. At the cognitive level, learning involves understanding ideas and explaining them in one's own words. At the epistemological level, it involves beliefs about what counts as scientific knowledge and how such knowledge is constructed and validated (Driver et al., 1994; Mortimer & Scott, 2003; Pozo & Crespo, 2021). At the motivational level, it involves goals, interest, and expectations of school-related and future utility, which sustain effort in the face of difficulty (Pintrich, 2003; Zimmerman, 2000).

Evidence indicates that these dimensions are related to students' academic performance (Gomes & Golino, 2012). Students who describe learning as understanding tend to report intrinsic interest and curiosity. Those who describe learning as fulfilling a requirement tend to report instrumental motivation, that is, studying to pass, obtain grades, and achieve future goals, a pattern described in national studies on motivational orientation (Martinelli & Genari, 2009; Paiva & Boruchovitch, 2010). In the final years of K-12 education, these motivations often coexist within the same student. In science, moreover, conceptions function as domain-specific epistemological beliefs, for example, a focus on correct answers and procedural training, which is associated with a more dualistic epistemology and mechanized study strategies (Tsai, 2002; Tsai & Kuo, 2008).

In the specific case of Natural Sciences, conceptions of learning are not neutral, as they incorporate epistemological beliefs about the field itself (Chinelli et al., 2010; Diniz & Assis, 2024). If the subject is viewed as a set of correct answers transmitted by the teacher, learning means copying, avoiding terminological errors, and reproducing information later. If science teaching is understood as an investigative activity, learning involves formulating questions, testing hypotheses, interpreting results, justifying claims based on evidence, and revising explanations (Munford & Lima, 2007; Sasseron, 2015; Sasseron & Carvalho, 2011). Students' conceptions of learning in science reveal whether knowledge is perceived as a closed list of facts or as the practice of constructing explanations about natural phenomena, thereby redefining the student's role in the classroom and affecting performance in investigative activities and teaching practices (Almeida & Gomes, 2024; Köhnlein & Peduzzi, 2005; Lederman, 1992; Mortimer & Scott, 2003; Santos & Mortimer, 2000; Tsai & Kuo, 2008).

In this sense, learning science preserves aspects common to other school learning processes, such as attention, memory, comprehension, self-regulation, and monitoring of one's own study. At the same time, it assumes an epistemological specificity. In Natural Sciences, learning also involves understanding how claims are justified, what role is played by evidence, models, investigative procedures, and forms of argumentation. For this reason, students' conceptions can be interpreted as part of their epistemic cognition, that is, their beliefs about what counts as knowledge, how an explanation is justified, and how the quality of a school scientific response is evaluated (Hofer & Pintrich, 1997; Chinn et al., 2011; Greene et al., 2016).

This framework is consistent with the Brazilian National Common Curricular Base for Natural Sciences, which establishes goals such as interpreting natural and technological phenomena, arguing based on evidence, critically analyzing information, making informed decisions regarding health, environmental, and consumption issues, and relating scientific knowledge to everyday situations (Ministry of Education, 2018). From a curricular standpoint, learning science involves understanding, justifying claims, and taking evidence-based positions. Students' beliefs about what Science is and what counts as learning thus become indicators of alignment between what is prescribed and what is experienced. In contexts strongly oriented toward examinations and practice routines, knowledge atomization tends to emerge, that is, the study of isolated topics without conceptual articulation, which distances learning from the investigative and argumentative practices prescribed by the BNCC and is often associated with surface approaches to learning (Tsai & Kuo, 2008; Tsai, 2002).

In school practice, routines and interactions communicate these conceptions. Classes centered on copying and rapid responses reinforce a reproductive view of learning, whereas contexts that value time for asking questions, discussing errors, and relating content to everyday life promote an investigative and explanatory view of scientific learning (Driver et al., 1994; Mortimer & Scott, 2003; Sasseron, 2015; Sasseron & Carvalho, 2011; Ministry of Education, 2018). Students' conceptions therefore reflect both curricular principles and the actual teaching conditions they experience (Carvalho, 2014).

The relationship between conceptions of learning and pedagogical practices also manifests itself in the cognitive and affective changes that mark school progression. Transitions between educational stages constitute decisive moments for the reconfiguration of these conceptions and for the consolidation of academic identities. Classroom discourse tends to become more authoritative and denser in technical language, conceptual abstraction increases, and students are expected to become fluent in representations and notations specific to science, which are often perceived as academic barriers (Duit, 2009; Lemke, 1993; Mortimer & Scott, 2003). At the same time, pressure related to educational choices and performance increases, interacting with task-value expectations and self-efficacy beliefs, with effects on engagement, persistence, and intentions to pursue the field. In this context, students construct identity narratives that combine conceptions of learning, epistemological beliefs about what counts as learning in science, and motivational orientations concerning the purpose of studying Science, with implications for school and vocational trajectories (Sandoval, 2005).

Against this backdrop, we shift the focus to students' voices. This study examines how students in the final years of elementary school and in high school describe what they regard as learning Natural Sciences. We sought to map conceptions and identify reported approaches to studying, characterizing the experience of learning science from the students' own perspective. We also investigated the extent to which there is a mismatch between what students say learning science means and what they report doing to learn. Educational stage was considered to contextualize the composition of the participant group, but not as an axis for systematic comparison between elementary and high school students, because the design and composition of the corpus do not support comparative inferences. We began from the hypothesis that such a mismatch exists and guided the analysis through the following questions, articulated within the study objective itself: What conceptions of learning science emerge in students' accounts? What approaches do they report using? To what extent is there incongruence between declared conceptions and reported practices?

Methodology

This is a qualitative, descriptive-exploratory study guided by a perspective inspired by phenomenography. The phenomenographic inspiration was adopted in its classical sense, as the investigation of the different ways in which people experience, understand, and describe a phenomenon, following the tradition inaugurated by Marton and Säljö (1976). The focus is on the different ways in which students understand the phenomenon of "learning science"; thus, the aim is to map qualitative variations in conceptions. Data were collected through an open-ended questionnaire, and the responses were examined using content analysis, with categories constructed from classical dimensions of the phenomenographic literature on conceptions of learning. The study seeks thematic saturation rather than the estimation of population parameters; therefore, the design prioritizes interpretive depth.

Context and Participants

The study was conducted in a part-time public school located in the urban area of a municipality in the state of Goiás, Brazil. The institution serves students in the final years of elementary school, regular high school, and high school integrated with technical education, with an approximate age range between 13 and 18 years.

To characterize the research setting, educational indicators made available by the National Institute for Educational Studies and Research Anísio Teixeira (INEP, n.d.) were considered. In the 2023 Basic Education Development Index (IDEB), the school had an average score of 4.6 in the final years of elementary school and 4.4 in high school. The IDEB ranges from 0 to 10 and combines information on students' performance in the assessments of the Basic Education Assessment System (Saeb) with school flow data, especially approval rates, thereby providing a synthesis of aspects related to students' learning and school trajectories. Regarding the composition of the teaching staff, the most recent data made available by INEP indicate that 92.3% of teachers working in elementary school and 96.3% of teachers working in high school hold a higher education degree. Regarding students' socioeconomic profile, the school is classified at level V of the Socioeconomic Level Indicator (INSE). This indicator considers information about goods and services available in the household, access to resources such as the internet, and parents' or guardians' educational level. Level V places the school slightly above the national average, indicating that students generally have more favorable socioeconomic conditions than the average of Brazilian schools.

The school was selected by convenience and because it included classes from the final years of elementary school and from high school, which made it possible to explore different moments of K-12 education within the same institutional context. In Brazil, K-12 education comprises early childhood education, elementary school, and high school. In this study, participants were students from the final years of elementary school, which correspond to grades 6 to 9, and from high school, the subsequent stage organized into three years. The choice of the school was consistent with the qualitative and exploratory design of the research, as the aim was not to compare schools or estimate trends in the public school system, but to understand the variation in meanings attributed to learning science in a concrete school context. Therefore, the results should be interpreted as analytical and contextual contributions, rather than as statistical generalizations to the public school system of Goiás or Brazil. All eligible students were invited to participate. The inclusion criterion was enrollment in regular education between the 8th grade of elementary school and the 2nd year of high school.

The empirical corpus comprised 56 students from the public school system of the state of Goiás, distributed between the 8th and 9th grades of elementary school and the 1st and 2nd years of high school. The mean age was 15.36 years (SD = 0.98). Of the participants, 35.7% (n = 20) identified as boys and 64.3% (n = 36) as girls. Regarding school level, 46.4% (n = 26) were enrolled in elementary school and 53.6% (n = 30) in high school. The study followed all ethical principles for research involving human participants and was approved by the Research Ethics Committee under CAAE No. 90710625.6.0000.5540. Supplementary materials for the study, including the questionnaire used and additional results tables, are available on the Open Science Framework (OSF): https://osf.io/6c4ej/overview.

Data Collection Instrument

The questionnaire was designed to elicit conceptions of learning in science through open-ended and contextualized responses, focusing on the variety of meanings students attribute to learning. Its construction was based on the analytical axes and examples of item formulation presented by Freire and Duarte (2016) and Figueira and Duarte (2019). Based on these studies, conceptions were considered describable in terms of the functions and factors of learning, as well as the nature, processes, and contexts of learning. The instrument was structured into six complementary dimensions: referential, processual, contextual, functional, factorial, and learning problems, with three open-ended questions in each dimension.

The development of the questionnaire followed four steps: identification of the theoretical dimensions recurrent in studies on conceptions of learning, adaptation of these dimensions to the domain of Natural Sciences, formulation of open-ended questions in language accessible to students, and semantic clarity review before administration. The instrument did not have a psychometric purpose, as it sought to generate open-ended accounts for qualitative analysis. Thus, validity was treated as coherence among the questions, theoretical dimensions, and research objective, rather than as the estimation of metric properties.

The referential dimension sought to characterize what students understand by learning science, for example, acquiring information, reconstructing meanings, and developing the capacity to explain natural phenomena. The functional dimension explored the purposes attributed to learning, such as school-related and extra-school utility, citizenship education, and practical application in everyday situations. The processual dimension focused on how learning occurs, privileging the description of strategies effectively used, for example, explaining in one's own words, solving problems, testing what had been studied, and relating content to personal experiences. The contextual dimension addressed where learning takes place, including the classroom, home, community spaces, and digital environments, with emphasis on experiences recognized outside formal class time. The factorial dimension investigated what helps or hinders learning, such as characteristics of teaching, content, the study environment, and peer interactions. Finally, the learning problems dimension sought to identify perceived obstacles and coping strategies proposed by the students themselves, which makes it possible to understand how they mobilize resources when facing difficulties.

Data Analysis

The analysis followed Bardin's (2015) content analysis technique, organized into three articulated stages. In the pre-analysis stage, the corpus was constituted with all valid responses, an initial exploratory reading was conducted for familiarization, the recording units and context units were defined, and an initial framework of provisional categories was developed in line with the six dimensions of the instrument. During material exploration, coding was performed by two researchers, initially independently, through line-by-line reading of the responses and grouping of meaning units into categories and subcategories based on semantic similarity. The coding decisions were then compared, and disagreements were discussed until analytical consensus was reached. Categorization was predominantly inductive, guided by the axes of the reference studies, and iterative, with successive revisions until the labels and inclusion and exclusion criteria were stabilized. In the treatment and interpretation of results, relative frequencies of occurrence by category were synthesized, representative excerpts were produced, and inferences were developed in dialogue with the literature. The consolidated categories and their descriptors are presented in the Results section, organized by instrument dimension, with examples of student excerpts and specific interpretive syntheses for each section. Quotations from students' responses appear in quotation marks, followed by an anonymized identifier in parentheses. We used the format (Est. XX, level), in which XX is a sequential number from the anonymized database and level indicates the school stage, EF for the final years of elementary school and EM for high school.

The relative frequencies presented were calculated to synthesize recurrences in the corpus and guide the reading of qualitative patterns. They should not be interpreted as population estimates or as a basis for statistical inference. The mismatch between declared conceptions and reported practices was examined through the articulation of different dimensions of the instrument. To this end, responses about what learning means and how students recognize that they have learned were compared with responses related to study strategies, coping with difficulties, and preparation outside the classroom. Thus, the mismatch was interpreted as a qualitative convergence among categories, rather than as the result of a statistical test of correspondence between variables. The analysis did not include a formal calculation of interrater agreement; however, coding was conducted by two researchers, with comparison of categories, discussion of disagreements, and return to the corpus whenever semantic overlap was identified.

Results and Discussion

To contextualize the profile of the participant group, we begin with indicators of students' engagement with Natural Sciences. These data describe the interpretive context of the corpus, but they were not used as variables for comparison across school levels. Declared interest showed a bimodal distribution: 1.8% (n = 1) of participants reported no interest, 7.1% (n = 4) reported little interest, 33.9% (n = 19) were neutral, 28.6% (n = 16) reported interest, and 28.6% (n = 16) reported high interest. Curiosity about specific areas was concentrated mainly in Biology (58.9%), followed by Physics (25.0%) and Chemistry (16.1%).

The results are then presented in three interrelated axes: (1) Conceptions and practices of learning in Natural Sciences, centered on the referential and processual dimensions; (2) Learning Natural Sciences: where it takes place, what it is for, and what motivates it, focused on the functional and contextual dimensions; and (3) Mediation, difficulty, and context in learning, which addresses the factorial dimensions and learning problems. This organization structures the results according to the meanings attributed to learning, its uses, its contexts, and the factors that facilitate or hinder it.

Conceptions and Practices of Learning in Natural Sciences

Most students described learning as the mastery of school content and facts. This perception can be observed in the following statement: "Acquiring systematic knowledge about the world around us, enabling us to understand natural phenomena and even technological advances" [Est. 16, EF]. A smaller proportion articulated an epistemological frame, emphasizing investigation, data analysis, and evidence-based explanations, as in the following example: "... learning science means discovering the world through scientific data, knowing something that has been proven ..." [Est. 15, EM]. Other students referred to personal interest and life projects, whereas some responses were vague and did not present an explicit conceptualization (Figure 1).

When explaining "how they know they have learned," productive indicators predominated. For example, one student stated: "I know I have learned when I can explain it in my own words and use what I have learned to understand other things" [Est. 16, EF]. External indicators, such as grades and correct answers, appeared in a secondary position. Some students associated learning with long-term retention, and a subset expressed uncertainty about whether they had learned. In the distinction between learning and memorizing, the contrast was clear. Learning was described as understanding and applying, whereas memorizing was described as repeating without understanding. This distinction can be observed in the statements "Learning means understanding and being able to use what was learned; memorizing is just decorating it and forgetting it later" [Est. 33, EM] and "... memorizing is merely decorating the things explained without actually having learned them" [Est. 37, EF]. Few students did not perceive a clear difference or provided vague responses. This discursive consensus coexists with the initial definition of "learning science" as the accumulation of content (Figure 1).

Figure 1

Students' conceptions of learning science, criteria for recognizing learning, and distinction between learning and memorizing

Metacategory	Subcategory/Indicator	%
Definition of what it means to learn science	Knowledge about the world and school content	57.1
	Scientific way of thinking, investigating, and explaining with evidence	10.7
	Personal interest and life project	12.6
	Undefined or vague response	19.6
Criterion for knowing that one has learned	Explains in one's own words, answers questions, teaches someone else	48.2
	Good grade, correct answer on a test or exercise	14.3
	Remembers after some time, long-term retention	12.5
	Uncertainty about having learned	7.1
	Undefined or vague response	17.9
Learning versus memorizing	Learning means understanding and applying; memorizing means repeating without understanding	85.7
	Does not see a clear difference	5.4
	Undefined or vague response	8.9

The students' accounts compose a hybrid picture of conceptions of learning science. A school-based view of knowledge as a collection of content predominates, favored by transmissive routines of exposition and memorization. At the same time, signs of an investigative framework emerge, in which learning involves explaining phenomena based on evidence, articulating conceptual relations, and constructing arguments in interaction with peers and instructional materials. This reflects a recurrent tension in Brazilian schooling (Munford & Lima, 2007; Sasseron & Carvalho, 2011). The coexistence of these perspectives is related to the heterogeneity of conceptual thinking in the meaning-making of scientific concepts. Different ways of thinking about the same concept may coexist and be mobilized by individuals in diverse learning situations, which helps explain the simultaneous presence of content-centered and investigative discourses in the classroom (Mortimer et al., 2014). This result can also be interpreted through the notion of practical epistemologies: the responses indicate situated ways of deciding what counts as knowing, explaining, and justifying in the classroom, even though these criteria do not always translate into coherent study strategies (Sandoval, 2005).

In addition, the evidence suggests the formation of mixed learning profiles, in which cognitive processing, self-regulation, and motivational orientations combine in different ways, with implications for the quality of engagement. National studies have shown that students who use self-regulated strategies in an integrated manner tend to show greater engagement and better academic performance (Boruchovitch, 2014; Dias et al., 2020; Ganda & Boruchovitch, 2018), which reinforces the importance of considering these elements in analyses of learning science in the Brazilian school context.

The distance between how students define learning and the criteria they use to recognize that they have learned is noteworthy. In their definitions, a content-centered vocabulary persists. In their criteria, however, metacognitive indicators gain prominence, such as explaining in one's own words, transferring to new situations, and supporting answers with justifications. This tension indicates that there is a repertoire for moving practices toward deeper and more self-regulated approaches, provided that teacher mediation makes these criteria explicit and incorporates them into tasks, rubrics, and formative feedback, thereby supporting monitoring and control of one's own learning (Freire & Gustavo, 2006; Gomes, 2011; Gomes & Golino, 2012; Pintrich, 2003; Zimmerman, 2000).

The contrast between learning and memorizing operates as an interpretive key: learning is associated with understanding and application, whereas memorizing is perceived as repetition without understanding and rapid forgetting. This consensus legitimizes practices of explanation, evidence-based argumentation, error analysis, and revision of ideas, bringing the classroom closer to an epistemological perspective compatible with school scientific practice. When such routines become part of everyday classroom life, students' experience becomes aligned with what the BNCC prescribes for Natural Sciences (Ministry of Education, 2018; Driver et al., 1994; Munford & Lima, 2007; Sasseron, 2015; Sasseron & Carvalho, 2011). To this end, it is advisable to reduce curricular signals that communicate that learning is equivalent to copying and reproducing, and to expand experiences that invite students to ask questions, make predictions, test, justify, and revise. By turning into routine what students themselves recognize as evidence of having learned, schools reduce the gap between what is prescribed and what is experienced, foster self-regulation, and create conditions for sustainable conceptual change, including during moments of greater symbolic density and performance pressure, typical of the transition to the final years of elementary school and to high school (Mortimer & Scott, 2003; Pozo & Crespo, 2021; Sandoval, 2005).

Regarding routines, when a new topic is introduced, many students revisit the content on their own, review it, search for supporting materials, watch videos, and produce summaries or concept maps, as illustrated in the statement: "I pay attention and try to do the activities; when I cannot, I ask for help and watch video lessons on the internet" [Est. 07, EM]. In the classroom, immediate efforts appear, such as paying attention, taking notes, and asking the teacher questions. Requests for help from classmates are mentioned less often. In out-of-class study, a review pattern centered on rereading notebooks and materials from the term predominates: "I start by looking at my notebook, and I observe each content and focus on each one I have doubts about ..." [Est. 25, EF]. Active practices, such as solving questions, redoing activities, and trying to answer without looking, appear for a smaller proportion of students. A small group did not indicate a defined strategy. When a practical activity or experiment goes wrong, most students report adjusting and repeating the procedure, checking materials and steps, and seeking external support, for example from the teacher, videos, or comparison with classmates. Cases of inaction are minor (Figure 2).

Figure 2

Students' conceptions of strategies for learning science and managing errors in practical activities

Metacategory	Subcategory/Indicator	%
New content in class	Solves it immediately, pays attention, takes notes, asks the teacher	30.4
	Asks classmates for help	3.6
	Revisits the content later on their own, reviews it	58.9
	Undefined or vague response	7.1
Out-of-class study	Rereading notebooks and materials from the term	64.3
	Active practice, questions, redoing activities, answering without looking	25.0
	Undefined or vague response	10.7
Experiment that went wrong	Adjusts and repeats the procedure, checks materials and steps	50.0
	Seeks external support, asks the teacher, searches for videos, compares with classmates	41.1
	Inaction or does not know what to do	8.9

The students' accounts indicate that they activate a relatively stable sequence when faced with new content. In the classroom, immediate efforts predominate, such as paying attention, taking notes, and asking the teacher questions. Outside the classroom, students most often revisit the content on their own by reviewing materials, seeking support, and producing summaries. This arrangement combines signs of self-regulation with a strong emphasis on surface-processing strategies, which is consistent with the central role of rereading in everyday study, even when students claim to value understanding and explaining in their own words (Gomes, 2011; Pozo & Crespo, 2021).

The more modest presence of active practices, such as solving questions, redoing activities, and trying to answer without consulting materials, suggests a gap between the criteria students use to recognize that they have learned and the routines they actually mobilize. In metacognitive terms, there is monitoring of one's own progress; however, control still privileges comfortable methods with lower cognitive cost (Dunlosky et al., 2013). Transforming this disposition into learning gains requires making the use of active learning strategies more frequent, as these strategies support comprehension, transfer, and long-term retention. They also help align the curriculum and formative assessment with what students themselves report as evidence of learning (Mortimer & Scott, 2003; Pintrich, 2003; Zimmerman, 2000).

The persistence of passive strategies, despite students' recognition of active learning criteria, can be understood through the distinction between perceived fluency and durable learning. Rereading and reviewing notebooks produce rapid familiarity and a sense of mastery, whereas solving questions, attempting to recall without consulting materials, and analyzing errors require greater effort and may initially create the impression of poorer performance. This desirable difficulty tends to support retention and transfer, but it is not always spontaneously chosen by students, precisely because it increases cognitive cost and makes gaps in understanding more visible (Bjork, 1994; Dunlosky et al., 2013; Rivers, 2021; Roediger et al., 2011; Rowland, 2014).

The responses concerning error management in practical activities reveal an important asset. When something goes wrong, many students describe debugging steps, adjusting procedures, and seeking external support, including comparison with classmates. This repertoire is close to school scientific work, involving the checking of materials, the examination of variables, and the revision of hypotheses. This pattern shows that classroom culture can cultivate epistemic perseverance, provided that there is structure, time, and mediation to make explicit why errors are informative and how they can be transformed into evidence to justify changes in procedure. This brings students' experience closer to an investigative view of Natural Sciences (Munford & Lima, 2007; Sasseron, 2015; Sasseron & Carvalho, 2011).

Learning Natural Sciences: Where It Takes Place, What It Is For, and What Motivates It

The students describe learning Natural Sciences as a process distributed across multiple spaces. Some report learning better in the classroom with the teacher, due to step-by-step explanations and the opportunity to ask questions. Another group highlights practical activities and laboratory work, where they can observe experiments and "learn by doing." References to individual study at home or on the internet also appear, as do combinations that articulate initial explanation with subsequent practice. Among the facilitators, the clarity of teachers' explanations, the organization of content, and responses to students' questions predominate, as illustrated by the statement "The teachers' explanations ..." [Est. 51, EM]. Practical activities and demonstrations also emerged, along with conditions of focus and silence that support sustained attention.

Among the obstacles reported, noise and classroom indiscipline stood out: "... in my opinion, what hinders me the most is the people, because there are times when I really cannot concentrate on the activity because of the loud noise" [Est. 51, EM]. These were followed by tiring classes, lessons that were difficult to follow, and personal difficulty in maintaining attention (Figure 3). These factors help explain why, despite valuing understanding in the classroom, many students prefer to study outside school (42.9%) rather than in the school environment (37.5%), while the remaining students perceive no difference (19.6%).

Figure 3

Students' conceptions of learning contexts in Science and main facilitators and obstacles

Metacategory	Subcategory/Indicator	%
Where students learn best	Classroom with explanation and opportunities to ask questions	28.6
	Laboratory and practical activities	21.4
	Individual study at home or on the internet	19.6
	Combination of spaces and stages	30.4
What helps	Clear teacher explanation	60.7
	Practical and demonstrative activities	23.2
	Focus and silence	12.5
	Undefined or vague response	3.6
What hinders learning	Noise and indiscipline	66.1
	Tiring class or class that is difficult to follow	10.7
	Personal difficulty maintaining attention	16.1
	Undefined or vague response	7.1

The students' accounts outline an ecology of distributed learning. The classroom appears as a starting point, due to step-by-step explanations and the possibility of asking questions, whereas the laboratory and practical activities function as spaces for observation and testing ideas. Outside school, individual study and the use of online resources consolidate and reorganize meanings. Many students describe combined pathways: first they listen, then they do, and finally they review. This sequence reinforces the investigative logic prescribed by the BNCC (Ministry of Education, 2018; Sasseron & Carvalho, 2011).

Among the facilitators, three elements stand out: clear explanation, progressive organization of content, and opportunities to ask questions. These elements help translate everyday language into the register of school scientific practice, which encourages participation and reduces conceptual noise in the transition among terms, representations, and procedures specific to the field (Lemke, 1993; Mortimer & Scott, 2003). Practical activities and demonstrations complement teacher mediation because they make variables, measurement procedures, and causal relations visible. This movement allows explanation to move beyond the verbal level and become supported by observation, recording, and evidence-based argumentation (Munford & Lima, 2007; Sasseron, 2015; Sasseron & Carvalho, 2011).

The reported obstacles point to an environmental dimension. Noise, indiscipline, and fatigue drain attention and inhibit participation, shortening the time of meaningful contact with the object of study (Aquino, 1998, 2016; Rabelo et al., 2014). Classes with a fast pace and limited opportunities for review aggravate the problem because they make it more difficult to organize teaching work and manage routines that support learning (Souza & Anic, 2024). When the classroom climate supports questions without embarrassment, error analysis, and periodic systematization, the quality of the experience changes, as argumentation based on data and records begins to guide the construction of explanations, rather than merely verbal reproduction (Mortimer & Scott, 2003; Munford & Lima, 2007; Sasseron, 2015; Sasseron & Carvalho, 2011).

Regarding the purposes of learning science, many students attribute to the subject a broad explanatory function: understanding how the world works, nature, the human body, and physical and chemical phenomena. This is illustrated by the statement: "... to help understand how the world works, from the human body to natural phenomena. It serves to develop critical thinking, solve problems, and make conscious decisions in everyday life" [Est. 51, EM]. In a secondary position, students mention uses for everyday life, for example, making decisions and taking care of health and the environment. References to Science as an essential part of schooling also appear, as do rarer mentions of preparation for future stages, such as exams and careers. In relation to motivation, three vectors stand out. Intrinsic motivation, as in "Many things motivate me, but specifically, curiosity. The way Science awakens this in us is incredible ..." [Est. 56, EM], coexists with instrumental motivation, as in "... the desire to become something in the future" [Est. 10, EF], and with situated motivation, which increases when the class includes clear explanation, everyday examples, practical activities, and teacher participation: "... I feel more motivated when the teacher shows practical examples, conducts experiments, or relates the content to real situations ..." [Est. 50, EM].

Regarding the use of learning outside school, lack of recognized application predominates. Most students report not remembering or not yet having used what they learned: "No. Because knowledge of Science ... does not solve problems in my life" [Est. 10, EF]. Among those who report application, examples of self-care and everyday decisions predominate, as observed in "Yes, when I learned about nutrition and used it to improve my diet" [Est. 33, EM], followed by occasional cases of using strategies to solve problems or explain something to other people: "... answering a question my mother had about something, and I remembered what the teacher said in class about the subject" [Est. 14, EF] (Figure 4).

Figure 4

Students' conceptions of the purposes, motivations, and uses of learning science outside school

Metacategory	Subcategory/Indicator	%
What learning Science is for	Explaining how the world works	43.6
	Everyday utility, decision-making, and citizenship	23.6
	Essential school education	27.3
	Preparation for further studies and careers	5.45
What helps	Intrinsic motivation, curiosity, and fascination	38.2
	Instrumental motivation, utility, and performance	36.4
	Pedagogical or classroom-situated motivation	25.5
Use outside school	Does not recognize application	57.1
	Self-care and everyday decisions	35.7
	Use of learning strategies or explanation to others	7.1

Students attribute to Science a broad explanatory function, namely understanding phenomena related to the body, nature, and technology, and they recognize that this understanding supports everyday decisions and scientific citizenship. The subject also appears as a constitutive part of school education. Mentions of preparation for future stages are present, but they do not structure the main meaning attributed to learning science. This framing is consistent with the BNCC, which emphasizes interpreting phenomena, arguing with evidence, and making informed decisions about health, the environment, and consumption. It therefore legitimizes practices that connect content to the lived world rather than restricting the experience to decontextualized definitions and procedures (Ministry of Education, 2018; Dunlosky et al., 2013; Mortimer & Scott, 2003).

At the motivational level, curiosity and fascination coexist with instrumental goals and with situated motivation, which increases when lessons provide clear explanations, relevant examples, and practical activities. In terms of self-regulation, this suggests that personal reasons and instructional conditions reinforce one another, sustaining effort in the face of difficulty. The literature indicates that intrinsic interest and utility value can be cultivated through instructional design, for example, by making explicit what the content is for and by creating opportunities for choice and participation, while still considering the expectations and performance goals that structure students' educational trajectories (Deci & Ryan, 2000; Eccles & Wigfield, 2002).

However, a gap remains between perceived value and the application of Science in everyday life. Many students do not recognize immediate use of what they learn, which points to difficulties in transfer. This mismatch does not invalidate the meaning attributed to the subject; rather, it indicates that the bridges between learning and using knowledge are still fragile. Transfer tends to be strengthened when schools create explicit connections with real problems, when students plan where and how to use a concept, and when review activities require application in new contexts (Hulleman & Harackiewicz, 2009; Mortimer & Scott, 2003).

Mediation, Difficulty, and Context in Learning Natural Sciences

Students describe learning in science as modulated by three combined axes: teacher mediation, perceived difficulty of the content, and external and emotional conditions. Mediation appears in the foreground, especially through the emphasis on clear "step-by-step" explanations, examples, and practical activities: "... what helps the most is the teacher's explanation and the activities, because they show whether we have really learned ..." [Est. 26, EF]. This is followed by difficulties related to vocabulary, symbols, and pace: "... the most difficult part is the very complex terms, which are very different from what we see in everyday life" [Est. 18, EF], as well as environmental factors such as noise, "Excessive noise in class can be very disruptive" [Est. 30, EF], fatigue, anxiety, and lack of materials. Interest across areas is heterogeneous. Biology is preferred because of its association with the human body, nature, and animals: "...

Biology, especially Marine Biology. Studying each part of the body of marine animals fascinates me, where they come from, why they exist, what they are, and what their function is on Earth ...” [Est. 56, EM]. Physics and Chemistry are perceived as more difficult because they involve calculations and greater abstraction, although a smaller group prefers them because of their fascination with phenomena and technology. The influence of classmates is perceived as helpful, as an obstacle, or as irrelevant, with a substantial proportion reporting little or no influence (Figure 5).

Figure 5

Students’ conceptions of factors associated with learning science

Metacategory	Subcategory/Indicator	%
What helps or hinders learning	Clear teacher mediation, step-by-step explanation, examples, and practices	44.6
	Perceived difficulty of the content and pace	19.6
	External and emotional conditions, noise, fatigue, anxiety, lack of materials	35.7
Interest in areas of Natural Sciences	Broad interest in all areas	23.2
	Preference for Biology	35.7
	Preference for Physics and/or Chemistry	10.7
	Depends on the topic and its utility	16.1
	Low general interest	14.3
Influence of classmates	Classmates help, explain, answer questions, share materials	23.2
	Classmates hinder learning, noise and distractions	17.9
	Mixed influence	16.1
	No influence	42.9

The centrality attributed to teacher mediation indicates that, for these students, the main trigger for learning is the quality of classroom guidance. Clear explanations, step-by-step sequencing, and the use of examples and practical activities function as bridges between everyday language and scientific language, reducing conceptual friction and expanding productive participation through questions and justifications (Lemke, 1993; Mortimer & Scott, 2003; Sasseron & Carvalho, 2011). In contrast, the most frequently cited difficulties are related to technical vocabulary, notations, and pace, which points to the need for representational support, translations across registers, and strategic review to stabilize understanding.

External and emotional conditions, such as noise, fatigue, anxiety, and lack of materials, appear as modulators of effective attention time. These results reinforce that classroom climate and infrastructure are not peripheral; rather, they constitute the enabling conditions for mediation to operate. Routines involving partial synthesis, error analysis, and opportunities to ask questions without embarrassment tend to mitigate these effects and sustain effort when the content requires greater abstraction, especially in topics with high symbolic load, in line with evidence on learning regulation and conceptual change (Pozo & Crespo, 2021; Mortimer & Scott, 2003).

The pattern of interest is heterogeneous. Biology gains traction because of its proximity to the body and nature, whereas Physics and Chemistry are perceived as more difficult. Even so, accounts of fascination with phenomena and technology suggest that interest in these areas increases when teaching connects models to meaningful situations and concrete uses. From a motivational perspective, it is useful to explore utility value and situational interest, that is, to make explicit what the content is for, create brief application tasks, and provide meaningful choices, which can increase expectations of success and sustain persistence (Eccles & Wigfield, 2002; Hulleman & Harackiewicz, 2009).

The influence of classmates is ambivalent. It is helpful when there are clear norms and tasks that require students to think first on their own, attempt to answer without consulting materials, compare solutions, and explain their reasoning to a peer (Azevedo et al., 2022; Salas et al., 2024). Without structure, interaction becomes noise and dispersion. Qualified mediation remains the central axis; linguistic and pacing difficulties require explicit procedures, and environmental conditions require intentional management (Francisco, 2024; Silva & Almeida Júnior, 2018). Interest is sensitive to the topic and to perceived use, and peer collaboration only adds value when it is designed as a shared epistemic practice (Meyer et al., 2018; Salas et al., 2024).

When facing difficulties, many students begin by studying alone through rereading, searching, and watching video lessons: “I try to review and identify where the gap is” [Est. 09, EM]. Some seek help from the teacher or classmates: “I ask a classmate for help, look in my notebook, or ask the teacher for help” [Est. 37, EF]. Negative emotional reactions, such as frustration and discouragement, also appear: “to be honest, I get frustrated and kind of give up when I think it is too difficult for me, but when I do not give up, I try to ask someone questions” [Est. 52, EM]. Regarding the areas perceived as most difficult, Physics and Chemistry predominate. Biology appears as challenging in specific topics, such as genetics and anatomy. In their suggestions to teachers, students especially request more practical classes, with experiments, laboratory activities, group work, debates, and connections to everyday life: “Having more practical classes, going more often to the laboratory, doing experiments, watching videos about it” [Est. 06, EM]. They also request clearer explanations and checks for understanding: “Trying to facilitate the understanding of the topic addressed...” [Est. 12, EM], as well as more individualized support. One group considers current teaching practices adequate (Figure 6).

Figure 6

Students' conceptions of reactions to difficulty, the most challenging areas, and suggestions for support in Science

Metacategory	Subcategory/Indicator	%
First reaction when facing difficulty	Tries to solve it alone, rereading, video lesson, searching	46.4
	Seeks help from the teacher or classmates	30.4
	Negative emotional reaction, frustration and discouragement	23.2
Area perceived as most difficult	Physics and Chemistry	55.4
	None in particular, depends on attention and effort	26.8
	Biology, specific topics such as genetics and anatomy	5.4
	Vague, does not specify the focus of difficulty	12.5
Suggestion to the teacher	Make the class more practical and interesting	41.1
	Explain more clearly and step by step, review, and check for understanding	25.0
	Improve classroom conditions, silence, and organization	1.8
	It is already good, maintain current practices	32.1

When facing difficulties, students tend to study on their own through rereading, searching, and watching video lessons; some seek help from the teacher or classmates, and negative emotions also appear. This pattern combines monitoring with low-cognitive-cost choices, which is understandable, but limits the consolidation of understanding (Bjork, 1994; Dunlosky et al., 2013; Rivers, 2021; Roediger et al., 2011; Rowland, 2014).

Regarding the areas perceived as most difficult, Physics and Chemistry concentrate the main barriers, whereas Biology appears as challenging in specific topics. The instructional implication is direct. It is necessary to reduce extraneous load through language and representational support, make explicit the relations between terms and notations, and connect models to salient phenomena and concrete uses. Sequences that alternate conceptual presentation, brief investigation, and situated application tend to increase utility value and expectations of success without diluting rigor, thereby sustaining effort in more abstract topics.

Students' suggestions converge toward a lesson design that integrates meaningful practices. They ask for experiments, laboratory activities, group work, debates, and connections with everyday life, as well as clearer explanations and more individualized support. This translates into spaced routines of activities followed by short tasks involving attempts before consultation, explicit rubrics defining what counts as a good explanation, formative assessment, and partial syntheses. Such an arrangement brings students' experience closer to what the BNCC prescribes for Natural Sciences and improves the transition between everyday discourse and scientific discourse in the classroom (Ministry of Education, 2018; Mortimer & Scott, 2003; Sasseron, 2015; Sasseron & Carvalho, 2011).

Conclusions and Implications

The results indicate that students mobilize a relatively consistent set of criteria to recognize learning in science, especially explaining in their own words, justifying answers, and applying ideas to new situations. At the same time, their study routines remain centered on review and rereading. This mismatch between discourse and practice appears consistently: students recognize productive indicators of learning, yet when studying, they resort to passive strategies that produce a sense of fluency. The analysis suggests that metacognitive judgments, lesson organization, and classroom climate directly influence this choice of strategies.

The results also show that the meaning attributed to the subject is broad: understanding how the world works and making decisions in everyday life, although most students do not recognize frequent uses of what they learn outside school. This pattern indicates a problem of transfer, not necessarily a lack of perceived value. When practical situations emerge, especially in the face of experimental failures, students activate procedures of debugging and verification. This reveals potential for bringing conceptions of learning closer to epistemic practices valued in curricula. School stage and the nature of the content modulate this scenario: Biology appears closer to everyday experience, whereas Physics and Chemistry are perceived as more abstract and symbolic.

From an instructional perspective, the results point to feasible pathways. It is important to make explicit, in each topic, what counts as learning: explaining with evidence, arguing, modeling, and revising. It is also important to replace part of the time devoted to rereading with retrieval practice, spaced review, and error analysis. In classes that report noise and fatigue, attending to classroom climate and organizing periods of attention is part of the pedagogical intervention itself. Peer collaboration tends to work better when roles are clearly defined, when tasks require students to explain and compare solutions, and when there are moments of checking without consulting materials.

In terms of contribution, the study offers an integrated account of the conceptions, study routines, and classroom conditions that shape the experience of learning science in K-12 education. By bringing together what students say, what they do, and the conditions under which they do it, the study helps identify low-cost leverage points for aligning practices with evidence. Regarding limitations, some responses were vague, suggesting the need to improve instructions and categories in future data collection. It would also be useful to distinguish the quality and frequency of use of each strategy and to relate profiles of conceptions and routines to performance indicators.

The limitations of this study derive from its qualitative design, the use of an open-ended questionnaire, and the selection of participants from a single public school. The group is small and not representative; therefore, the findings should be understood as analytical contributions concerning a specific context. The transferability of the results depends on comparison with similar school contexts, rather than on statistical generalization to the Brazilian or Goiás public school systems. The responses are self-reports, which involve the risk of social desirability and selective memory. The study is cross-sectional and does not allow causal inferences or conclusions about change over time. Independent measures of proficiency, classroom observations, and task records were not included; thus, triangulation among discourse, practice, and outcome was lacking. In addition, although the group included students from the final years of elementary school and from high school, school stage was used only for contextualization, not for systematic comparison between educational levels. Future research should expand the participant group and the diversity of schools, combine interviews, observations, and think-aloud protocols with indicators of performance and self-regulation over time, and test instructional interventions that adjust external regulation, for example, formative feedback and planned review activities.

Authors' Contribution

Conceptualization: Silva, J. I. L., Menezes, J. P. C.; **Data curation:** Silva, J. I. L., Menezes, J. P. C.; **Formal analysis:** Silva, J. I. L., Menezes, J. P. C.; **Investigation:** Silva, J. I. L.; **Methodology:** Silva, J. I. L., Menezes, J. P. C.; **Project administration:** Silva, J. I. L., Menezes, J. P. C.; **Resources:** Silva, J. I. L., Menezes, J. P. C.; **Supervision:** Silva, J. I. L., Menezes, J. P. C.; **Validation:** Silva, J. I. L., Menezes, J. P. C.; **Visualization:** Silva, J. I. L., Menezes, J. P. C.; **Writing – original draft:**Silva, J. I. L., Menezes, J. P. C.; **Writing – review & editing:** Silva, J. I. L., Menezes, J. P. C.;

Data Availability Statement

The data is avaliable at: https://osf.io/6c4ej.

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