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Knowledge of mathematics and chemistry embedded into integration curriculum materials

Conocimiento de matemáticas y química incorporado en los materiales curriculares integradores

Connaissance des mathématiques et de la chimie intégrée dans le matériel curriculaire d'intégration

Conhecimento da matemática e da química incorporadas a materiais curriculares integradores

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Abstract

The article is structured around the objective of understanding Mathematics and Chemistry embedded into integration curriculum materials in the Natural Sciences area, assessed and approved within the scope of the PNLD 2021. For this documentary research, we selected the teacher's manual from a material defined as an integration project. After reading the introductory part of the presentation texts and guidance for developing two projects using such material, the analysis was guided by discussions of curriculum integration, work with projects, the analysis was guided by discussions of curriculum integration, work with projects and the knowledge of curriculum embedded Mathematics and Chemistry (KCEMC). The results indicate that the introductory part and the development of both projects lack transparency in conceptualizing curriculum integration, working with projects, and organizing content, which can restrict professional teaching knowledge and imply teaching practices that can diverge from the purposes of the curriculum material.

Keywords: Curriculum materials, Curriculum integration, Work with projects.

Resumen

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El artículo se estructura a partir del objetivo de conocer las Matemáticas y la Química incorporadas a los materiales curriculares que integran el área de Ciencias Naturales evaluados y aprobados en el marco del PNLD 2021. Es una investigación documental para lo cual se seleccionó el manual del docente de un material caracterizado como el Proyecto Integrador. Luego de la lectura de los textos de presentación, en la parte introductoria, y orientaciones para el desarrollo de dos proyectos del material mencionado, el análisis fue orientado por discusiones de integración curricular, trabajo con proyectos y conocimientos de Matemática y Química incorporados al currículo (KCEMC). Los resultados indican que, tanto en la parte introductoria como en el desarrollo de los dos proyectos analizados, existe una falta de transparencia en la conceptualización de la integración curricular, el trabajo con proyectos y la organización de contenidos, lo que puede restringir el conocimiento docente profesional e implicar la enseñanza. prácticas que pueden desviarse de los propósitos del material curricular.

Palabras clave: Materiales curriculares, Integración curricular, Trabajar con proyectos.

Résumé

L'article est structuré à partir de l'objectif de connaître les Mathématiques et la Chimie incorporées dans des matériaux curriculaires qui intègrent le domaine des sciences naturelles évalué et approuvé dans le cadre du PNLD 2021. Il s'agit d'une recherche documentaire pour laquelle il a été sélectionné le manuel de l'enseignant d'un matériau qualifié de Projet Intégrateur. Après avoir lu les textes de présentation, dans la partie introductive, et des conseils pour le développement de deux projets du matériel susmentionné, l'analyse a été guidée par des discussions sur l'intégration curriculaire, le travail avec des projets et la connaissance des Mathématiques et de la Chimie incorporées dans le curriculum (KCEMC). Les résultats indiquent que, tant dans la partie introductive que dans le développement des deux projets analysés, il y a un manque de transparence dans la conceptualisation de l'intégration curriculaire, le travail avec des projets et l'organisation des contenus, ce qui peut restreindre les connaissances pédagogiques professionnelles et impliquer l'enseignement pratiques qui peuvent s'écarter des objectifs du matériel curriculaire.

Mots-clés : Matériel curriculaire, Intégration du curriculum, Travailler avec des projets.

Resumo

O artigo estrutura-se a partir do objetivo de conhecer a Matemática e a Química incorporadas a materiais curriculares integradores da área de Ciências da Natureza avaliados e aprovados no âmbito do PNLD 2021. Trata-se de uma pesquisa documental para a qual foi selecionado o manual do professor de um material caracterizado como Projeto Integrador. Feita a leitura dos textos de apresentação, na parte introdutória, e de orientação para o desenvolvimento de dois projetos do referido material, a análise foi orientada pelas discussões de integração curricular, trabalho com projetos e do conhecimento da Matemática e da Química incorporadas ao currículo (KCEMC). Os resultados indicam que, tanto na parte introdutória quanto no desenvolvimento dos dois projetos analisados, há ausência de transparência da conceitualização de integração curricular, trabalho com projetos e organização dos conteúdos, o que pode restringir o conhecimento profissional docente e implicar práticas de ensino que podem divergir dos propósitos do material curricular.

Palavras-chave: Materiais curriculares, Integração curricular, Trabalho com projetos.

Knowledge of mathematics and chemistry embedded into integration curriculum materials

In 2019, within the scope of the Programa Nacional do Livro e do Material Didático [National Book and Teaching Material Program — PNLD], Notice n. 3/2019 called for the registration and evaluation of didactic, literary works, and digital resources for the High School PNLD 2021, presenting a differentiated proposal for curriculum materials, which, until its last edition, included exclusively the disciplinary organization.

Notice n. 3/2019 presents five types of materials called objects. One of the innovative proposals for this level of education is the works of Object 1, chosen in 2021 for the four-year cycle, the Projeto Integrador [Integrative Project] and the Projeto de Vida [Life Project]. Those materials include activities aligned with students' daily practices, adopting an integrating approach based on the guidelines of the Base Nacional Comum Curricular [National Common Curricular Base — BNCC] (Brasil, 2018). This proposal seeks to break with disciplinary logic, i.e., with the fragmentation of the curriculum into subjects. We call it *integrating curriculum materials* the ones aimed at curriculum integration, which present pedagogical innovations in comparison to those traditionally evaluated and distributed, implying the teacher-curriculum relationship and requiring these professionals to mobilize knowledge to read, interpret, assess, select, and put into practice the purposes brought by the curriculum materials.

The focus of the research we present here, the Integrative Project, consists of a single volume with six projects per area of knowledge, four of which address themes integrating STEAM[3], youth protagonism, media, and education and conflict mediation. The other two projects are free-choice.

Integrating curriculum materials in Natural Sciences and their Technologies promotes learning situations both for teachers who teach Chemistry and for those who teach Physics and Biology, also incorporating Mathematics knowledge. Considering integrated knowledge, these situations require teachers to mobilize and build knowledge to identify pedagogical innovations and perceive affordances — possibilities for pedagogical action — when reading and interpreting teaching guidelines and when evaluating and selecting tasks to be developed by students.

Curriculum development with the Integrative Project materials requires teachers'

[3] Methodological approach that integrates Science, Technology, Engineering, Art, and Mathematics.

analysis of its pedagogical proposal and study to expand their knowledge of the curriculum, projects and curriculum integration, and an approach related to the concepts of the subjects involved and embedded into these materials. It requires organization of time and space, classroom management, planning, and mobilization of knowledge to read and interpret the knowledge embedded into the materials — including Chemistry and Mathematics knowledge — and evaluate and select activities to put into practice teaching projects. The proposed curriculum integration also requires teachers' change in attitude to plan and develop teaching practices with the material since they may be used to working with proposals based on disciplinary logic but not developing projects that articulate knowledge from different subjects and areas of knowledge.

Therefore, this article[4] is guided by *the objective of learning about Mathematics and Chemistry embedded into integrating curriculum materials in Natural Sciences, evaluated and approved within the scope of PNLD 2021*. Next, we will address the conception of integration based on project work.

Curriculum integration

By highlighting the importance of the relationship between teachers and integrating curriculum materials — and understanding the knowledge these professionals construct or mobilize when reading, interpreting, evaluating, selecting, devising practices, and making use of integrative materials, in particular, Mathematics and Chemistry — we agree with Beane (2003) when discussing that knowledge environments can provide new conceptions of curriculum in educational theory and practice and can also broaden and deepen the various knowledge for teachers and students.

A curriculum is an essential tool that outlines the trajectory to be followed by teachers and students in the search for knowledge relating not only to content but to the set of experiences, behaviors, cultures, and practices inherent to it. A curriculum regulates both teaching practices and student learning. Sacristán (2013) addresses the curriculum as a construction of different responses to possible options. It is a battlefield that reflects political, economic, religious, and identity struggles.

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[4] This article makes up the master's degree thesis (Machado, 2023) defended in the Postgraduate Program in Education at the Universidade Estadual de Montes Claros, organized in multipaper format, written by the first author and guided by the second author.

Curriculum contents are usually organized in a disciplinary way; however, considering the context of the purposes of education, there are other ways of organization, one of which is the articulation between different subjects so students can better understand, contextualize, and attribute meaning to what is taught, resulting in the expansion of knowledge for a comprehensive education.

According to Zabala (2002), educational institutions must have a good curriculum, know how to respect culture, organize spaces, and work with routines and projects to generate quality service. In this sense, curricular integration in Natural Sciences materials, especially Chemistry — and considering Mathematics as an important set of integrative knowledge — is an essential strategy for expanding student learning since the PNLD 2021 proposal aligns with such curriculum organization, i.e., integration.

Knowledge of the curriculum is something that teachers need to build and mobilize so that they can improve their pedagogical practice, select content and activities, and evaluate and select curriculum materials. To achieve this, it is necessary not only to have knowledge of the specific content of the Natural Sciences area but also to mobilize knowledge about what theoretically and ideologically supports that content approach, including knowledge of the curriculum (Oliveira *et al*., 2021).

In his studies, Beane (2003) argues that some investigations have shown that students whose curriculum consists, in general, of an integrative approach achieve identical or higher performances in standardized knowledge tests than those who experience only one approach per subject, except in abstract and highly specialized areas.

From this perspective, the BNCC mentions curriculum integration and work based on integrative projects. Also, some works evaluated and distributed by PNLD 2021 were prepared with integrative concepts and organized through projects. This teaching modality may attract students and stimulate teachers, leading them to break with the routine use of textbooks, seeking new ideas and alternative, creative, and innovative solutions for their practices.

In this scenario, we seek to relate Mathematics and Chemistry, based on the concept of curriculum integration, taking as a reference a theoretical framework for professional teaching knowledge based on the relationship between the teacher and curriculum materials.

Curriculum materials and the embedded knowledge

In Collopy (2003), Remillard and Kim (2017) and Januario (2022), it is discussed that' objectives, interests, beliefs, values, and expectations regarding curriculum materials can influence their use and impact teachers' professional knowledge of Mathematics. Our understanding is that this relationship also affects professional knowledge of Chemistry.

The need for a specific body of knowledge for a Chemistry teacher is mentioned by Maldaner (2008), who argues that there is specific knowledge for them. This knowledge must circulate, be recreated in teacher education bodies, and be valued in the broad and specific social context of producing chemical facts. It is, therefore, knowledge that goes beyond "giving good chemistry classes" (Maldanar, 2008, p. 270). For Martins, Garbo, and Soares (2021), understanding teaching knowledge in a theoretical-didactic dimension implies using tools that actually identify and characterize this knowledge.

Remillard and Kim (2017) present the Knowledge of Curriculum Embedded Mathematics model (KCEM), which establishes how mathematical ideas and notions are presented in curriculum materials and seeks to "to make much of the invisible work of teaching visible and to uncover specialized forms of knowledge that might be developed in teachers" (p. 67). In this sense, Collopy (2003) illustrates the dynamic and diverse nature of teachers' learning opportunities through reading, interpreting, evaluating, and selecting materials. Considering the research theme presented here, this model also serves as a reference to understand the knowledge of Chemistry that teachers activate when they relate to the curriculum materials of this subject.

The KCEM theoretical model deals specifically with Mathematics. Nevertheless, it can potentially analyze knowledge from other subjects embedded into materials to support curriculum development. Based on the study by Remillard and Kim (2017), we will discuss the Knowledge of Curriculum Embedded Mathematics and Chemistry — KCEMC, Figure 1, inspired by and adapted from the KCEM, based on its four dimensions.

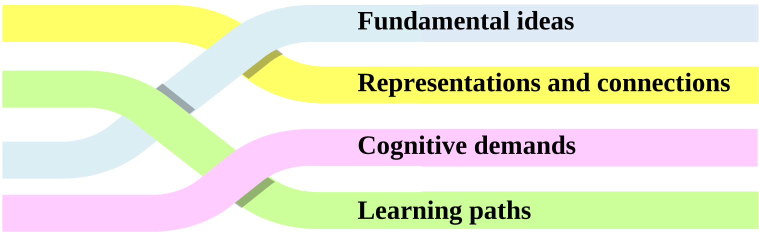

Figure 1.

Knowledge of Curriculum Embedded Mathematics and Chemistry (Inspired by Remillard & Kim, 2017)

Fundamental ideas refer to the justifications of procedures in approaching and presenting mathematical and chemical content. Some are presented to students as techniques and interpreted as "tricks" to solve an activity. Implicit in the techniques, which may appear without sense and meaning to students, there are the mathematics fundamental ideas, which come to fruition through procedures that show reasons, i.e., justifications based on mathematical knowledge. Just like in Mathematics, in Chemistry, these justifications are also present, and some may be more explicit than others. As an example, we cite the teaching of chemical bonds, which comprises fundamental ideas about physical and chemical properties, occurrences, obtaining and using chemical elements and their compounds; coordination compounds; structure and nomenclature of complexes and also the three main bonding models used: the simple electrostatic model, the Valence Bond Theory (VBT) and the Molecular Orbital Theory (MOT).

According to Remillard and Kim (2017), these ideas are present in learning objectives, activities, and pedagogical suggestions and guidelines regarding curriculum materials. They must be seen as possibilities for action (affordances) with the materials and be recognized in the evaluation that teachers make of the materials — or part of them — when planning and carrying out their classes to create the conditions or enhance existing ones so that students construct learning.

Representations and their connections concern the variety of models or representations of content in curriculum materials, contributing to different approaches to the same concept. Remillard and Kim (2017) state that in Mathematics, this dimension includes the various representations that specific content can assume and the connections between them; for example, algebraic expressions, language, tables, tables, diagrams, schemes, and other figural elements, considering the emphasis on how knowledge can be transformed and represented to make it accessible to students. Similarly, content in Chemistry, for example, chemical bonds, assumes different representations and connections with each other: figural representations, language, charts, tables, problem situations, theoretical models, and computer simulation, among others.

Cognitive demands are related to the degree of complexity of the activities, and the different reasoning expected that students express when solving the proposed tasks. One of the challenges of education, especially the teaching of Chemistry — and one of the teacher's main purposes — is to create conditions for students to develop the ability to reason, think, reflect, and use acquired knowledge to build new ones or even reach a result expected from some activity that demands cognitive effort beyond their knowledge. Bensaude-Vincent (2009) suggests a "chemical style" of reasoning, constituting an analytical tool that allows investigating the creation and development of a chemical way of thinking about materiality, of designing its manipulation and social use, whose rationality is based on a specific epistemic space for the production and creation of theories and artifacts.

Then, to solve an task, students must use knowledge already constructed during class experiences or in contexts outside the school, and to do this, they must use paths that demand a certain amount of cognition. Such tasks require more superficial and more complex reasonings. Whatever the proposed activity requires specific reasoning from the student and establishes a different type of cognitive demand. Cognitive demand comprises the types of mathematical (and chemical) reasoning needed for an activity. Smith and Stein (2009) present a categorization for activities based on the level of demand expected from students for their resolution, these being low-level cognitive demands, which are *memorization tasks* or *procedural tasks without connections*; and high-level cognitive demands, represented by *procedural tasks with connection* and *tasks that involve mathematics (and chemistry) doing*.

Learning paths include the recognition of learning sequences in relation to the curriculum. It is about understanding how content or concept is situated within a larger set of learning aimed at the Mathematics and Chemistry curriculum, which may be within a set of activities, a given academic year, or several years that make up the students' school life. This dimension is defined as the understanding of the interrelationships between the contents of the basic education curriculum and their purposes for forming concepts prescribed for students.

Those paths imply the teacher's competence in relating the contents planned for a given academic period with those covered in later years or vice versa. Therefore, it concerns professional teaching knowledge regarding the curriculum and curriculum materials for students' mathematical and chemical education.

Methodological procedures

Research is relevant in the field of curriculum and curriculum materials such as textbooks — in particular, the teacher's manual — and their implications for the education of subjects and social practices since they can take different aspects of public curriculum policies, teacher education, curriculum, and materials to support curriculum development. In Brazil, textbooks, materials prepared by education departments and the relationship between teachers and those materials have been the focus of Mathematics Education research, highlighting the potential of those materials as operators of teaching practice and inducers of learning, both for students and teachers.

The research portrayed here aims to discuss how Mathematics and Chemistry embedded into Natural Sciences integrating curriculum materials, evaluated and distributed within the scope of PNLD 2021, can influence teachers' class planning and provide learning situations for their students. Therefore, considering the purposes of this work, this is a qualitative approach research, corresponding to a documentary analysis.

Fiorentini and Lorenzato (2006) highlight that documentary analysis uses primary sources, i.e., data and information that have not yet been treated scientifically or analytically. The document to be analyzed is a teacher's manual for a textbook (curriculum material) evaluated and distributed within the scope of the 2021 PNLD for high school.

The book analyzed has integration as a curriculum organization, with work with projects being the methodological approach. The investigation focuses on Object 1, the didactic work of the integrative project type in the area of Natural Sciences and its Technologies. For the analysis, we considered the teacher's manual from the book *Identidade em Ação: Ciências da Natureza e suas Tecnologias* [Identity in Action: Natural Sciences and their Technologies], authored by Sônia Lopes, Rosana Louro Ferreira Silva, Sérgio Rosso, and Átila Iamarino, published in 2020 by Editora Moderna. Two Chemistry teachers chose this book from two schools in the state education network of Minas Gerais, who agreed to participate in a research of which the study portrayed here is part.

Among other books placed for the teachers' appreciation, all evaluated and distributed by 2021 PNLD, coincidentally, both chose the same title, indicating the two projects they decided to work on during their classes. The teachers did not present their motivations for choosing this book and the two projects.

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The choice for this type of book, prepared from integrative projects, is due to its novelty compared to traditional books commonly used in Brazilian public schools. The teacher's manual for this book presents an introductory part with guidance on the organization of the work, suggestions on how each project can be developed, and suggestions for practices that can be adopted when planning classes. It contains a reproduction of the pages of the student book, with comments and answers to the activities and additional guidance and information for content development.

From this book, we consider two projects chosen by the collaborating teachers. The first, *O diálogo entre Arte e Ciência* [The dialogue between Art and Science], highlights youth protagonism and addresses youth cultures so that it can stimulate students' active participation from a civic perspective, prioritizing BNCC general skills, the specific skills in the area of Natural Sciences and its Technologies and some of its skills; and because it is an integrative project, skills and abilities from other areas of knowledge are also mobilized. The second, *Saúde e Aquecimento Global: como mídias informam ou desinformam* [Health and Global Warming: how media inform or misinform], focuses on content related to media education; addresses discussions about information and misinformation, the spread of fake news and how students use various media. Those projects, like the rest of the material, require the mobilization of knowledge of Mathematics to understand and solve their activities, as well as knowledge of Chemistry, Physics and Biology. Particularly, knowledge of Chemistry and Mathematics converges with the core of the discussion here.

Let us focus on the analysis, considering the proposal for curriculum integration, fundamental notions, representations and connections, cognitive demands, and learning paths.

Curriculum integration proposal

In Beane's (2003) understanding, a curriculum with an integrative approach plays a vital central role in students' construction of knowledge about a curriculum with a subject-based approach. *Identidade em Ação* has as curriculum integration an organizational proposal. However, in the presentation texts of the teacher's manual, interdisciplinarity and transdisciplinarity are mentioned as an articulation between chemistry, physics, and biology knowledge.

Reading the introductory part and the guidelines for the development of the two selected projects indicates the absence of explanation about curriculum integration, or even interdisciplinarity and transdisciplinarity, an aspect that can promote the understanding that these are similar concepts, which, for Aires (2011), requires understanding how knowledge is organized in terms of academic subjects and course subjects.

In the guidelines for project development, the text referring to the project *Saúde e Aquecimento Global: como mídias informam ou desinformam* does not explain these concepts: integration, interdisciplinarity, and transdisciplinarity. At the end of the project, however, suggestions for topics with an integrative approach are presented in the section *"Outras sugestões mantendo o objetivo do tema integrador"* [Other suggestions keeping the objective of the integrative theme] (Identidade em Ação, 2020, p. XLII). The text referring to the project *O diálogo entre Arte e Ciência* does not mention integration or interdisciplinarity.

In this material, interdisciplinarity is presented as a concept of curriculum integration, whereby activities seek to establish connections between knowledge from different subjects, given that knowledge is not compartmentalized, which corroborates Beane's (2003) ideas. For this author, curriculum integration occurs not only in school subjects but in experiences, articulating knowledge that makes sense for students' real lives.

Although the terms interdisciplinarity and curriculum integration are not synonymous, as highlighted by Aires (2011), we understand that in the material *Identidade em Ação* it is the interaction that occurs in various ways between two or more subjects within a curriculum organization — above all, Mathematics, Chemistry, Physics, and Biology — so that it can provide a broadening of experiences, contents beyond one subject, aiming to connect each school reality.

This variety of concepts is implicit in the curriculum organization of the material, as we can see in the following excerpt:

> However, interdisciplinarity, as we have already highlighted, is not the only form of interaction between subjects and areas of knowledge. (Identidade em Ação, 2020, p. IX)

The teacher's manual mentions concepts discussed by other authors, such as Hilton Ferreira Japiassu, one of the pioneers in proposing interdisciplinarity in Brazil, namely, multidisciplinarity, pluridisciplinarity, and transdisciplinarity without, however, explaining their meanings. These terms may be interpreted as synonyms, leading teachers to understand that they carry out teaching practices within these curricular organization proposals. It can also cause doubts about which project encompasses which concept, reverberating mistaken senses and meanings about teaching practices with integrative projects.

As it is material from a specific area, natural sciences and its technologies, the different contents of Chemistry, Biology, and Physics are integrated, and the proposal for curriculum integration can be observed in their projects (units). The integration of knowledge of the subject matters can be observed in several excerpts of the texts in the introductory part, as highlighted below:

> While global warming is a unifying axis that involves not only the cycles of nature that, to be understood, depend on knowledge of physics (light and solar radiation and changes in the physical state of matter), chemistry (carbon dioxide and its properties and chemical transformations) and biology (carbon cycle, fossil formation, photosynthesis and environment; their changes also directly impact society and the environment. (Identidade em Ação, 2020, p. XLVI)

> The concepts of biology appear when we consider notions of sustainable development. The areas of mathematics, engineering, architecture, art, and technology are present at different times, such as in the construction of models, lighting projects, assembly of circuits with Moser lamps, in the case of the hybrid model, making calculations and preparing a lighting project using Moser lamps. (Identidade em Ação, 2020, p. XXVI)

> This suggestion can be worked on with art, history, geography, and language teachers, among others. (Identidade em Ação, 2020, p. XCII)

And in excerpts from the guidance texts for the development of the two specific projects in question:

> This approach not only promotes the contextualization of this discussion to current health problems in different parts of Brazil but also helps us explore the transversality of the health topic, combining history with biology. (Identidade em Ação, 2020, p. L).

> Out of curiosity and to expand students' knowledge, it would be interesting to include the concept of ethnobotany here. To do this, turn to chemistry and biology teachers. (Identidade em Ação, 2020, p. LXXXIX).

As it is a specific work in Natural Sciences, the articulation with the Mathematics appears subtly in the texts, as we can see in the following excerpt from the introductory part of the curriculum material:

> When creating works of art, students can mention the presence of mathematical calculations and concepts from natural sciences, such as those used in the works of Leonardo da Vinci and other artists presented throughout the project. (Identidade em Ação, 2020, p. LXXXVI)

Similarly, integration with Mathematics appears subtly and implicitly in a few excerpts of the texts that accompany the projects, as the following excerpts illustrate:

> This skill is worked on, especially in step 5, where students are requested to analyze the infographic and interpret how human activity interferes with the carbon cycle when fossil fuels and biomass are consumed as resources. (Identidade em Ação, 2020, p. XLIV)

> This is another time when computational thinking can promote research, analysis, and understanding skills that will inform content production. Encourage students to break down the problem, identify patterns, abstract the patterns to other content, and build analysis algorithms. (Identidade em Ação, 2020, p. LIII)

Considering curriculum materials as key learning tools for students and teachers, Januario (2022) highlights the relationship between teachers and materials for teaching professional knowledge and the lack of theoretical references that may favor studying this relationship. The presentation texts mention the project-based learning methodology (PBL), presenting work with integrative projects as a teaching practice with transversal contemporary themes:

> This work presents six proposals for authentic and realistic integrative projects based on motivating and engaging themes for high school youth, linking school content to the social context. The projects, although different in terms of approaches, share their methodological basis: they start from an anchor, questions to survey previous knowledge, driving questions (goal/question declared for the project), brainstorming, collective planning, and production of artifacts, which are designed and modeled throughout the projects, aiming to be presented to the school and non-school audiences. (Identidade em Ação, 2020, p. XXI)

Zabala (2002) understands that educational institutions must have a good curriculum, respect culture, organize spaces, and work with routines and projects. He also highlights the need to transpose the specificities generated by disciplinary curriculum in search of a more systemic, global, integrative, and complex formation. The author discusses the proposal for a project-based methodology as an alternative for integrating curriculum content towards an education committed to students' interests. The analyzed book makes the proposal clear:

> Further, we explore the meaning of working with socio-scientific issues in teaching natural sciences and the contributions of project-based learning to integrated work with these themes. This analysis also speaks to the teacher's important role and pedagogical practice in guiding projects. (Identidade em Ação, 2020, p. III)

Like Remillard and Kim (2017), we understand that curriculum materials, based on their resources, can guide teachers in their pedagogical practices, providing opportunities to expand their knowledge when relating to the materials, mainly favoring changes in their pedagogical practices. Agreeing with Collopy (2003), the authors argue that teachers mobilize knowledge by reading, interpreting, evaluating, selecting and designing materials. In this way, Chemistry teachers can activate more in-depth and extemporaneous knowledge when interacting with such integrative materials.

Regarding the approach to working with projects, the material presentation texts in *Identidade em Ação: Ciências da Natureza e suas Tecnologias*, indicate guidance and details on working with projects, the role of the teacher and student in the development of projects, explaining what projects are and the PBL methodology:

> Like other active methodologies, project-based learning (PBL) finds its historical bases in the New School movement, which has as one of its greatest exponents the American philosopher and pedagogue John Dewey, although it was a movement that involved a bigger group of thinkers. According to this movement, education should be based on learning by doing, understood as a process of reconstruction and reorganization of experience by the learner and guided by the principles of initiative, originality, and cooperation (Dewey, 1959). (Identidade em Ação, 2020, p. V)

The material highlights an organized proposal centered on students and their social demands, encouraging learning to make coherent choices that align with their life project; that is, the activities involve the students' future, being able to identify each one's potential.

Moran (2018) clarifies that integrative projects are considered interdisciplinary since they occur when they integrate more than one subject, the teacher, or even an area of knowledge. They articulate various points of view and knowledge, presenting complex everyday issues and helping students to understand the connections between subjects and between school knowledge and the real world. In this way, they put students in contact with real problems, enabling them to learn and, at the same time, contribute to concrete solutions for the community, learning not only for themselves but to improve the lives of others (Rezende & Silva-Salse, 2021). Santos (2009), when considering learning from projects, suggests that these can be multidisciplinary, interdisciplinary, and transdisciplinary, and this classification is not watertight since many projects can take on features of more than one category.

We observe that the organization and presentation of the projects correspond to the conception discussed in texts in the introductory part of the curriculum material, in which the guidelines explain aspects that allow the teacher to design the chemistry class beyond the disciplinary organization.

Considering the proposed integrative approach, we identified the material did not explain the concept of integration nor the terms interdisciplinarity, transdisciplinarity, and multidisciplinarity. This variety of terms can promote misinterpretation and understanding of the curriculum integration proposal that diverges from the intentionality of the material, inducing work with projects in a disciplinary approach. The lack of transparency in the theorizations and conceptualizations underlying the curriculum material restricts teachers from building knowledge related to curriculum organization, methodological approach to content, and evaluation in teaching practices that consider issues of social relevance and content from different disciplines as themes embedded into the curriculum.

Fundamental ideas

According to the KCEMC, inspired by the studies of Remillard and Kim (2017), the *fundamental ideas* portrayed here refer to the implicit or explicit mathematical and chemical justifications in some activity resolution procedures. From students' point of view or depending on the teacher's approach, these ideas can be translated as *rules* or *tricks.*

In the material under analysis, we observed that the fundamental ideas of Mathematics and Chemistry are underlying the guidance texts for teachers and the introductory part of each project; for example, in the guidelines of *Step 4* from the project *O diálogo entre Arte e Ciência*, when mentioning the oxidation process, which involves "gain" and "loss" of electrons; also, when noting acid-base indicators, which include ideas about acids, bases, scales and Ph calculations (*hydrogen potential*): values greater than seven (> 7) for bases and less than seven (< 7) for acids. The fundamental ideas of Mathematics are perceived in the guidelines of *Step 5* from the project *Saúde e Aquecimento Global: como as mídias informam ou desinformam,* when relating graphs that represent the average temperature; also in *Step 2* from the project *O diálogo entre Arte e Ciência,* where proportionality properties are found, mentioning the presence of mathematical calculations and concepts from natural sciences used in Leonardo da Vinci's work (Vitruvian Man) and other artists presented throughout the project. Fundamental ideas from other content, such as Biology and Physics, are also present in some sections of the projects' development.

Despite being present in the project guidelines, the procedures presented throughout the project do not allow teachers to know what mathematically and chemically justifies the different ways of solving activities and what is popularly called rules. There is potential for understanding fundamental ideas, but it requires teachers to mobilize knowledge relating not only to the subject under their responsibility but to other areas of knowledge that are part of the curriculum.

The set of evidence regarding fundamental ideas has implications for the construction of teachers' knowledge to read and interpret Mathematics and Chemistry embedded into the curriculum material. As Davis and Krajcik (2005) argued, the lack of transparency of ideas and their explanations in the guidance texts and the presentation of expected answers can compromise lesson planning and interventions to collaborate in the progression of students' learning. This absence can compromise teachers' learning about properties and procedures that justify specific problem-solving strategies. When relating to these integrative materials, teachers need to mobilize knowledge beyond that inherent to their training area to understand the fundamental ideas in the project guidelines and concepts and approaches from other areas (subjects).

Based on Collopy (2003), we understand that the analyzed curriculum material presents resources that help teachers in their teaching practices due to the innovative way of approaching content and integrating different areas. At the same time, teachers must mobilize their knowledge to read and interpret the Mathematics and Chemistry embedded into it to expand what they know and better create learning conditions for their students.

Representations and connections

This dimension concerns how specific mathematical and chemical content can be approached and represented the types of instructions provided to students to solve the proposed activities. Taking the KCEMC model as a basis, the instructions and representations designed in the curriculum materials must be considered to make mathematical and chemical ideas and relationships accessible to students.

In the specific guidelines for the development of the two projects contained in the analyzed material, the book *Identidade em Ação: Ciências da Natureza e suas Tecnologias*, we see mainly in the project *O diálogo entre Arte e Ciência* that this dimension is found in the texts presented in a latent and subtle way. Teachers may not notice them when relating to the material. In the project *Saúde e Aquecimento Global: como mídias informam ou* desinformam, these representations appear explicitly to teachers, which facilitates their perception.

Figures, diagrams, and graphs exemplify the representations and connections relating to Mathematics and Chemistry contents, as illustrated on page 97 of the teacher's manual (Figure 2A), depicting oil and natural gas formation processes. The oil is fractionated through industrial processes, and products such as gasoline and diesel oil, for example, are extracted from it. Still on page 98 (Figure 2B), the diagram shows the numbers that indicate the amount (in billions of tons) of carbon involved in each circulation process represented, the amount of carbon stored in each extract (in billions of tons) and human impact on the process, both in terms of emissions and the amount of carbon that is reabsorbed by the cycle, all in billions of tons.

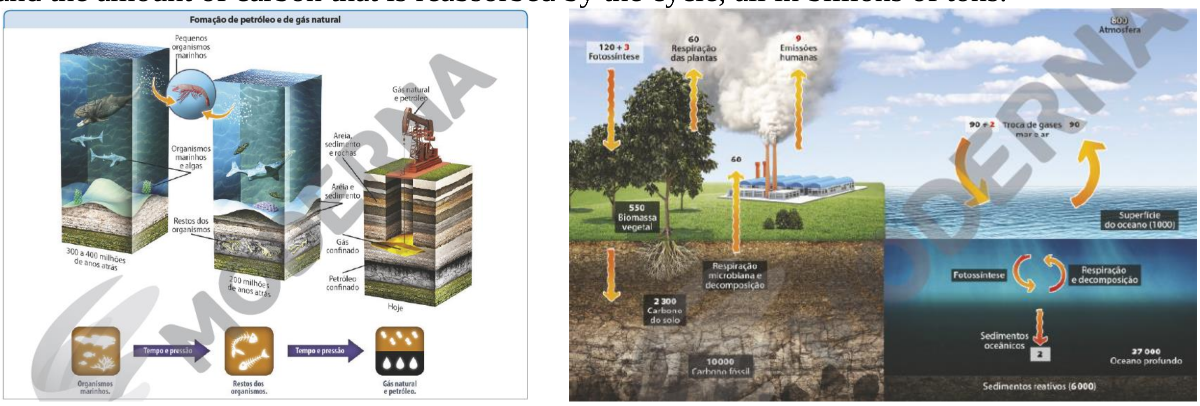

Figure 2 (A and B).

Example of representations and connections (Identidade em Ação, 2020, p. 97-98)

Finally, on page 99 (Figure 3), there is a graphic representation of the variation in the average concentration of carbon dioxide in the atmosphere between 1960 and 2019, in which a historical series of measurements of the concentration of atmospheric CO2 were made at the top of the volcano Mauna Loa, in Hawaii.

These representations are connected since the subject they cover is related to Organic Chemistry, particularly notions of the carbon cycle, fossil fuels, and organic functions. They are also related mathematically through algebraic language, scientific notation, and significant figures when mentioning "billion tons" and percentage per million (ppm).

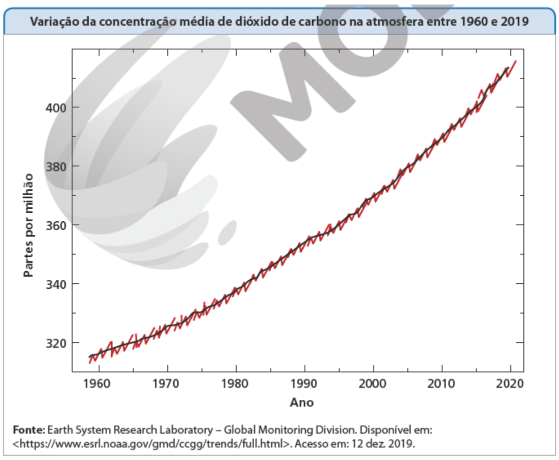

Figure 3.

Example of representations and connections (Identidade em Ação, 2020, p. 99)

When relating to integrating curriculum materials, teachers must mobilize mathematical and chemical knowledge, as well as knowledge from other subjects and areas, to develop the curriculum. In this process, they read and interpret knowledge embedded into the materials, build learning regarding the conceptual and methodological approach, and create better conditions for students' construction of learning situations. In this sense, we align with Collopy (2003), who emphasizes that, when planning their pedagogical practices and imagining how students can approach selected activities, teachers use the resources present in curriculum materials to reflect their actions and, consequently, learn from them.

Cognitive demands

Penalva and Llinares (2011) highlight that *cognitive demand* refers to the class and level of reasoning students need to solve a task, indicating what is achieved and what is learned at each level. When discussing this concept, Stein and Smith (2009) define a mathematical task as a segment of classroom activity dedicated to developing a particular idea. Inspired by these authors' ideas, we are extending their broad spectrum to chemical ideas through a mathematical task. In this sense, we consider that the student, to solve some tasks, needs to mobilize knowledge acquired in classroom experiences or in contexts outside the school, and to do so, they must use procedures that demand some amount of cognition. Some tasks will require more straightforward reasoning, while others will require more complex ones.

Analyzing the guidance texts for the development of the two projects, both do not present evidence for teachers regarding the different types of chemical or mathematical thoughts of students or even different degrees of complexity of the activities and their tasks. In the project guidance text *O diálogo entre Arte e Ciência*, an excerpt highlights the possible difficulties students might face when solving the third task of *Step 1*, as we can see:

> Students may describe difficulties using the digital spreadsheet, organizing the data obtained, grouping them, or choosing the graphical representation to present the collected data. (Identidade em Ação, 2020, p. LXXXVI)

Clearly, the difficulty presented concerns the use of the digital spreadsheet and data presentation, but not Mathematics and Chemistry knowledge. In this case, students may find it easier to mobilize knowledge of Mathematics and Chemistry, demonstrating an understanding of the concepts of these subjects. However, difficulty arises when exploiting digital spreadsheets to organize and present data. In other words, the difficulty is not explicitly found in the content of the subjects but in content related to technological tools, which can be manifested in the correct insertion of data in the cells of the spreadsheet, in the application of mathematical or chemical formulas to perform calculations, or even in formatting and visualizing data efficiently.

In the two projects analyzed, there is no explanation about the organization of activities in relation to what is cognitively demanded or even the importance of the variation in the complexity of the activities, therefore, the variation in the types of reasoning required. Based on the tasks listed in each activity, we realized that they need different types of reasoning, that is, different degrees of cognitive demands, as discussed by Stein and Smith (2009). Some tasks require high demands, while others require low demands during their resolution, with tasks that demand low cognition appearing in higher quantities.

From the discussions and categorizations about the levels of cognitive demands by Stein and Smith (2009), it is possible to observe that in both projects, there are activities with tasks of low cognitive level of types *procedures without a connection* and *memorization* and tasks with a high cognitive level, of types *procedures with connection* and *doing math/chemistry*. For example, Task 1 of project Step 4 *Saúde e Aquecimento Global: como mídias informam ou desinformam* involves only the reproduction of the facts that are in the text itself, with no connection with concepts, meanings, or procedures that support the fact. Through its text, the task requires a low cognitive level of the types *memorization* and *procedures without a connection.*

> Analyze the following text. Now, with your group, answer in your notebook. a) What was the reason the population gave for not being vaccinated against smallpox? b) What led the population to accept vaccination? (Identidade e Ação — Step 4, Task 1, 2020, p. 93)

Task 2 of Stage 5 of the same project demands a high cognitive level — *procedures with connection and doing mathematics/chemistry* — since, in it, students must interpret the information and the graphics and infer how we changed the planet's atmosphere with the burning of fossil fuels and the emission of greenhouse gases. Students still need to perform mathematical calculations to find the balance of carbon emissions made by humans from the graph.

> Analyze the following diagram representing the annual carbon cycle in the Earth's atmosphere and surface. Based on the diagram, do what is asked. a) Calculate the balance of emissions made by human beings. Is all the carbon we emit through our activities reabsorbed by nature? Explain your answer. b) What is the origin of the carbon that causes this difference? And where is it accumulating? c) Do forest fires and deforestation interfere with any part of the cycle? If so, which one? What result could this interference have on the final balance? (Identidade e Ação — Step 5, Task 2, 2020, p. 98)

We identified activities with low and high cognitive demand by analyzing the project *O diálogo entre Arte e Ciência*. We observed this in Task 1 of Stage 1, for which students need to prepare a research questionnaire. Then, apply, tabulate, and analyze the data obtained, which demands high cognition. As for Stage 3 of this project, in Task 1, students must describe and mention the properties of the materials present in works of art, in addition to noticing evidence of the rectilinear propagation of light — awakening them to some knowledge of Physics — when shadows are formed. In Task 2, students must mobilize knowledge about metals, metallic alloys and their properties and find works of art made from unusual materials — made of flowers, leaves, nails, teeth, hair, skeletons, waxes, and polymers, among others. In Task 3, they need to understand the importance of the bronze alloy, formed by the elements copper (Cu) and tin (Sn) in different proportions, to understand that the hardness and properties related to the mechanical resistance increase as the tin content increases.

> With your group, reflect on the artistic expression in monuments as presented in the report. a) List the places close to the region where you live where there are monuments

or other types of works of art; if possible, take photographic records. Remember to write down information about the photo, such as the date it was taken and the address of the work. This information is important for creating informative labels or captions. b) Share your records with other classmates. Together, exchange your learnings and choose some images that stand out both for the work they represent and the quality of the photography and collectively produce informative labels for these works. c) Organize an exhibition of these images at school, deciding the medium to broadcast and the language used. (Identidade em Ação — Step 1, Task 1, 2020, p. 178)

Analyze, with your group, the following images. Together, describe what sensations they awaken in you and list the possible types of scientific knowledge involved in their production. (Identidade em Ação — Step 3, Task 1, 2020, p. 183)

Search digital media for some works of art built with unusual materials and share with the group the one that catches your attention the most, including a description of the materials used. (Identidade em Ação — Step 3, Task 2, 2020, p. 184)

Research the different types of bronze alloys, their characteristics, and their main applications. Record this information in your notebook using a table. Additionally, explore the physicochemical characteristics of metals and how they can be applied in art. (Identidade em Ação — Step 3, Task 3, 2020, p. 184)

Tasks 4 and 5 require students to know the composition and physical-chemical properties of steel, such as malleability, thermal conductivity, and corrosion resistance, in addition to basic knowledge related to quantum physics, wave-particle duality of the electron to the equilibrium established when the sum of forces applied to a body is zero.

Steel, concrete, and glass are versatile and fundamental materials for civil engineering and enable the construction of buildings with innovative architecture. Search for more information about the chemical composition of these materials and their physical-chemical properties. Create a sketch of an architectural project for your municipality using these materials. This project must be relevant to your community. Describe the objectives of the project and then present it to your colleagues. (Identidade em Ação — Step 3, Task 4, 2020, p. 185)

With the requirements requested by the company and the list of works in hand, the group must prepare a repository of information about the works. To this end, we suggest: investigating how science was used in creating these works, whether as a concept, technique, or material in the final work, and some necessary scientific information, such as chemical composition and the scientific concepts used -chemical, physical or biological. (Identidade em Ação — Step 3, Task 5, 2020, p. 186)

In this project, the material production (video, podcast) is requested at the end of the Stage. Tasks 1, 2, and 3 of Stage 4 are classified as having low cognitive demands of the types *memorization* and *connectionless procedures* since students need to locate information in the text to answer the proposed questions. Task 4 is classified as being of high cognitive demand of the connected procedure type because it requires reflection on the advantages and disadvantages of each type of dye and the issues of unsustainability and health risks of obtaining others. They also need to make connections with the periodic table and the characteristics of the elements and also with acid-base indicators through the extraction of pigments with beetroot, carrots, kale or spinach, and red cabbage.

> What were the main difficulties encountered in the production of colored pigments? 2 Could you identify which chemical elements are involved in the composition of blue dyes? 3 Where can you find different colors of natural pigments in everyday life? (Identidade em Ação — Step 4, Task 1, 2020, p. 190)

> Considering the processes for obtaining natural and synthetic dyes, reflect on the sustainability issues of this production and indicate the advantages and disadvantages *of each type of dye.* (Identidade em Ação — Step 4, Task 4, 2020, p. 191)

The mathematical and chemical knowledge embedded in the tasks, which demand more or less cognitively from the students, implies the mobilization of teachers' knowledge when reading, interpreting, evaluating, and selecting such tasks contained in activities, as discussed by Collopy (2003) and Remillard and Kim (2017). Within the scope of the KCEMC, this is knowledge related to different degrees of cognitive demands, that is, levels of reasoning expected from students. Considering the analysis carried out, when planning and carrying out classes with the two projects of the curriculum material, teachers need to mobilize their knowledge to identify the possibilities and weaknesses of explaining the ideas, concepts, and procedures underlying the activities and, thus, think interventions to ensure the progression of student learning. It also requires the mobilization of knowledge regarding the organization and presence of content in the curriculum.

Learning paths

The *learning path* is related to how mathematics and chemistry content is distributed throughout a given school period and students' entire school trajectory. It refers to the teacher's recognition of the learning sequence of the curriculum. It concerns how concepts appear in particular contents located internally in a learning set aimed at the Mathematics and Chemistry curriculum. This is what Ball, Thames, and Phelps (2008) call *horizontal content knowledge*.

We identified throughout the two analyzed projects, whether in the introductory part or the specific part, that there is no explicit mention of the organization of the contents. However, we note that there is implicitly an organization since the Chemistry, Physics, Biology and Mathematics contents proposed there are part of the school curriculum for the three years of High School. Eventually, due to the specific characteristics of these materials being used in the three years of High School, they do not have a determined sequence; the contents appear according to the demands of project activities. Furthermore, we realize that the contents are proposed from the perspective of prior knowledge, as we can see in the following excerpt, present in the introductory part of the curriculum material under analysis:

> Some concepts and previous information are important for the development of this project. [...]. For the discussion about vaccination, students must be familiar with immunization and the functioning of our immune system. And, so that we can have the final discussion about global warming, students must be familiar with the greenhouse effect and the natural carbon cycle on our planet." (Identidade em Ação, 2020, p. XLIII)

Therefore, we identified that the learning path is implicit in the proposal; that is, it does not appear transparently in the texts, which implies a more significant requirement for teachers' knowledge mobilization to identify this organization or the presence of those contents. Therefore, those teachers who do not have or have not had the opportunity to establish discussions about this subject will certainly not pay attention to issues related to content organization, which may decontextualize, disregard, and modify the teaching purposes present in the projects.

Considerations

Depending on your conception of the curriculum, it can be considered as what regulates what is taught and what is learned in the school context. It can also be understood as the set of formative experiences that teachers and students are involved in and implicate. Thus, the curriculum materializes in the purposes and teaching practices; it is present in the curriculum materials it operationalizes, which incorporate principles and knowledge that, read and interpreted by teachers, contribute to their learning process.

Knowing Mathematics and Chemistry embedded into the integrative curriculum materials in Natural Sciences, evaluated and approved by the 2021 edition of the PNLD, is relevant for teachers to develop their practices and promote various teaching strategies involving students' learning. These materials must explicitly present to teachers ideas about curriculum integration, project work, fundamental ideas, levels of cognitive demands of activities, and learning paths.

Considering the integrating curriculum material, as analyzed above, the lack of transparency can compromise project development planning, the interventions to be made and, consequently, students' learning concerning justifiable procedures in specific strategies during the resolution of activities.

This absence, identified in the presentation and guidance texts for the development of the two projects, requires teachers to mobilize knowledge beyond that specific to their area of training and subject of activity. As it is an integrative material, in which concepts from other areas are integrated from projects, it requires the activation of knowledge when reading and interpreting the Mathematics and Chemistry embedded in them and when evaluating and selecting activities when planning and carrying out classes.

Regarding curriculum integration, the analysis indicates that the material mentions interdisciplinarity more, explaining less Mathematics as an integrating subject; the contents of Chemistry, Physics, and Biology appear more frequently, perhaps because it is a work in Natural Sciences, which is covered by these three subjects.

Finally, we understand that the relationship between teacher and curriculum materials involves the teaching and learning processes, which can influence how the curriculum is developed and how professional teaching knowledge can be broadened. Naturally, the research portrayed here can be expanded, aiming to facilitate and improve studies on contributions to professional teaching knowledge and the teaching of Chemistry and Mathematics, as well as the education of teachers who teach these two subjects.

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