Science Education and Interdisciplinarity: Current Practices and Future Pathways

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Abstract

Interdisciplinarity has been widely recognized as a relevant pedagogical approach in science education, promoting the integration of different knowledge domains [1,2]. This study examines teachers' perceptions and practices regarding interdisciplinarity in science education through a survey. The sample consisted of 150 pre-service and in-service teachers (n=150) from various educational levels and disciplinary backgrounds, aged between 25 and 60 (M=46.6). Most participants had academic training in biology, geology, physics, or chemistry. The findings indicate a widespread acknowledgement of interdisciplinarity's importance for scientific learning. Participants reported high levels of agreement concerning its benefits, particularly in fostering critical thinking (M=4.51), enhancing reasoning and problem-solving skills (M=4.56), and developing a holistic understanding of knowledge (M=4.57). Additionally, interdisciplinary approaches were perceived as significantly contributing to developing transversal competencies (M=4.66) and making learning more engaging and motivating (M=4.47). However, despite recognizing its advantages, several challenges hinder effective interdisciplinary implementation. The main obstacles identified include the lack of instructional time for planning and developing interdisciplinary activities (n=85; 56.7%), insufficient coordination between subjects (n=5; 3.3%), scarcity of adequate educational resources (n=24; 16.0%), and insufficient specialized training for interdisciplinary teaching (n=23; 15.3%). These findings suggest that while teachers recognize interdisciplinarity's pedagogical potential, structural challenges persist in integrating it into the educational framework. Addressing these issues requires institutional initiatives to foster teacher collaboration and enhance curriculum integration. Strategies such as joint planning across disciplinary areas, professional development programs, and providing adequate educational resources may significantly strengthen the impact of interdisciplinarity in science education.

Keywords: *Interdisciplinarity, science education, teacher perceptions, pedagogical challenges.*

1. Introduction

The challenges of 21st-century education demand innovative approaches capable of fostering more integrative, collaborative, and meaningful learning experiences. Interdisciplinarity has emerged as a response to the fragmentation of knowledge, aiming to connect concepts across disciplinary boundaries and respond to complex societal challenges [3]. In the context of science education, interdisciplinary approaches promote a deeper understanding of scientific phenomena by situating them in broader cultural, environmental, and technological contexts [3,4]. Recent studies have underlined the benefits of interdisciplinary teaching for fostering students' critical thinking, creativity, and problem-solving skills [5,6]. Moreover, interdisciplinary pedagogies align with frameworks such as STEAM (Science, Technology, Engineering, Arts, and Mathematics), which advocate for a holistic integration of disciplinary perspectives to enhance motivation and engagement [2]. Despite the theoretical support and policy incentives for interdisciplinarity, its practical implementation remains challenging. Time constraints, lack of collaboration between departments, insufficient training, and rigid curricula are recurrent obstacles reported by teachers [7]. In Portugal, although curricular flexibility has been increasingly encouraged through initiatives such as the Profile of Students at the End of Compulsory Schooling (*Perfil dos Alunos à Saída da Escolaridade Obrigatória*) [8], interdisciplinary practices are not yet fully consolidated in everyday teaching. This study investigates the perceptions and practices of pre-service and in-service teachers regarding interdisciplinary science teaching in Portugal. By analysing responses from a survey through questionnaire, this research aims to identify both the potential and limitations perceived by educators when implementing interdisciplinary in science education practices.

2. Methodology

A quantitative approach was employed through the administration of an online survey through a questionnaire composed of four sections. The target population included pre-service and in-service teachers affiliated with the disciplines Natural Sciences, Mathematics, Physics and Chemistry, Biology and Geology. The final sample included 150 respondents (n=150), aged between 25 and 60 years (M=46.6), with a majority reporting teaching experience at the lower and upper secondary levels. The following sections describe the sample and data collection instruments, the procedure, and data analysis and treatment techniques.

2.1. Sample

The sample consisted of 150 pre-service and in-service science teachers in Portugal, aged between 25 and 60 years (M=46.6). Descriptive statistics are summarised in Table 1.

Table 1. Sample characterisation (n=150).

Demographic Data		**Sample (n=150)**	
		n	**%**
Gender	Female	125	83.3
	Male	25	16.7
Background	Biology and Geology	71	47.3
	Physics and Chemistry	31	20.7
	Mathematics and Natural Sciences	20	13.3
	Mathematics	20	13.3
	Others	8	5.4
Age	Mean	46.6	
	Standard deviation	13.08	
	Minimum	25	
	Maximum	60	

Most participants reported teaching experience at the lower and upper secondary levels. In terms of professional status, 80% (n=120) were in-service teachers, while the remaining 20% (n=30) were enrolled in initial teacher education programmes. Most participants were female (n=125; 83.3%). Regarding disciplinary background, participants were primarily affiliated with Biology and Geology (n=71; 47.3%), followed by Physics and Chemistry (n=31;20.7%), Mathematics and Natural Sciences (n=20;13.3%), and Mathematics (n=20;13.3%). A small proportion (n=8;5.4%) indicated other subject areas or provided incomplete information about their teaching specialisation.

2.2 Data Collection Instrument

In line with the research objectives and methodological framework, a questionnaire was developed and implemented as the sole data collection instrument. It was designed to gather data on participants' demographic and professional backgrounds, teaching practices, and perceptions of interdisciplinarity in science education. The content of the questionnaire was reviewed and validated by three specialists in science education, based on a critical analysis of relevant literature and its alignment with the study's aims. The instrument comprised four main sections, each targeting specific information relevant to the research question (Appendix 1). Section 1 collected demographic data, including gender, age, academic qualifications, disciplinary area, teaching level, and years of experience, to characterise participants' profiles. Section 2 explored engagement in interdisciplinary teaching practices, such as prior participation and the subject areas involved. Section 3 focused on the themes addressed in interdisciplinary approaches. Section 4 gathered participants' perceptions of interdisciplinarity in science education through ten statements rated on a 5-point Likert scale, assessing perceived benefits for conceptual understanding, transversal competencies, motivation, critical thinking, problem-solving, and the development of a holistic view of knowledge. Data were processed and analysed using IBM SPSS© version 30. Descriptive statistics were applied to identify frequencies and trends, and means were calculated for responses to the Likert scale items.

3. Results

This section presents the analysis and discussion of the results obtained through the questionnaire. Responses to **Q1** reveal that most participants (n=143; 95.5%) reported having engaged in interdisciplinary teaching activities, while only a small minority (n=7; 4.7%) indicated that they had not. These results indicate a high level of engagement with interdisciplinary approaches among the participants. In the **Q2**, which explored the frequency of integrating content from other disciplines into teaching practices, the most common response was *sometimes* (n=83; 55.0%), followed by *frequently* (n=38; 25.3%). A smaller proportion reported doing so *rarely* (n=16; 10.7%) or *very frequently* (n=14; 9.3%). These findings suggest that interdisciplinary integration is generally present but occurs more often on an occasional than a systematic basis. The analysis of responses to **Q3** identifies the main obstacles perceived by teachers in implementing interdisciplinary activities in schools. Descriptive statistics are summarised in Table 2.

Table 2. Responses to **Q3** of the Questionnaire: Main Factors Hindering the Implementation of Interdisciplinary Activities in Schools (n=150).

Factors	Response frequency (n=150)*	
	n	%
Lack of available teaching time.	85	56.7
Lack of time for planning and development by teachers.	64	42.7
Lack of physical spaces (labs, classrooms, auditoriums).	30	20.0
Lack of specific training to apply these approaches.	25	16.7
Lack of specific educational resources.	25	16.7
Lack of interest from teachers.	24	16.0
Lack of funding to develop.	16	10.7
Institutional constraints (e.g., school leadership directives, lack of coordination).	15	10.0
Lack of student interest.	10	6.7
Lack of training offers in non-formal education and science dissemination (museums, botanical gardens, etc.).	6	6.7

** Participants could select more than one option; therefore, total mentions exceed the number of respondents. Percentages were calculated based on the total number of participants.*

The most frequently mentioned constraint was the lack of available teaching time (n=85; 56.7%), followed by the lack of time for planning and development by teachers (n=64; 42.7%). These findings underscore the significant impact of time-related limitations on interdisciplinary implementation. Other relevant barriers include the shortage of physical spaces such as laboratories or suitable classrooms (n=30; 20.0%) and the lack of both specific training to apply interdisciplinary approaches (n=25; 16.7%) and appropriate educational resources (n=25; 16.7%). Additionally, a notable portion of respondents pointed to the lack of interest from teachers themselves (n=24; 16.0%), as well as limited funding (n=16; 10.7%) and institutional constraints, including weak interdepartmental coordination (n=15; 10.0%). Less frequently cited factors included lack of student interest (n=10; 6.7%) and insufficient training opportunities in non-formal and informal educational contexts, such as museums or science centres (n=6; 6.7%). These results highlight the interplay between structural, institutional, and motivational barriers, suggesting the need for systemic support measures to enable interdisciplinary practice in science education.

The analysis of responses to **Q4** indicates that the most frequently addressed interdisciplinary topics are strongly linked to environmental education. Descriptive statistics are summarised in Table 3.

Table 3. Responses to **Q4** of the Questionnaire: Interdisciplinary Topics Addressed by Respondents (n=150).

Topic	Response frequency (n=150)*	
	n	n
Sustainability and Biodiversity	92	61.3
Climate Change and Environmental Impacts	77	51.3
Water Management	66	44.0
Energy and Sustainability	61	40.7
Health and Science	56	37.3
Food and Sustainability	55	36.7
Biotechnology and Environment	33	22.0
Scientific Technologies and Innovations	33	22.0
Science and Society	31	20.7
Science and Technology in Everyday Life	30	20.0
Space Exploration	24	16.0
Sustainable Cities	22	14.7
Geosciences and Natural Disasters	20	13.3
History and Nature of Science	19	12.7
Golden Ratio and Fibonacci Sequence	6	4.0
Others	1-2 mentions	0.7-1.4

** Participants could select more than one option; therefore, total mentions exceed the number of respondents. Percentages were calculated based on the total number of participants.*

Sustainability and Biodiversity was the most cited theme (n=92; 61.3%), followed by Climate Change and Environmental Impacts (n=77; 51.3%) and Water Management (n=66; 44.0%). These results highlight educators' prioritisation of ecological and sustainability-related issues in their interdisciplinary practices. Other relevant topics include Energy and Sustainability (n=61; 40.7%), Health and Science (n=56; 37.3%), and Food and Sustainability (n=55; 36.7%), reflecting growing concern with societal and public health challenges. Conversely, themes such as Golden Ratio and Fibonacci Sequence (n=6; 4.0%) and History and Nature of Science (n=19; 12.7%) were among the least mentioned, suggesting that mathematical-artistic and historical-scientific connections are less frequently integrated. The relatively low attention given by teachers to the Golden Ratio and Fibonacci Sequence indicates a promising area for further exploration, requiring the development of targeted interdisciplinary strategies and activities to better integrate these mathematical and natural concepts into science education. These results reveal both the dominant focus areas and potential gaps in the thematic scope of interdisciplinary science education.

The analysis of responses to **Q5** are summarised in Table 4, and it shows that the most frequently implemented interdisciplinary activity was *Group/Collaborative Work* (n=86; 57.3%), highlighting the emphasis on cooperative learning environments. This was followed by *Visits to museums, science centers, or natural spaces* (n=70; 46.7%), suggesting the relevance of non-formal education settings as complementary resources in interdisciplinary science teaching.

Table 4. Responses to **Q5** of the Questionnaire: Types of Interdisciplinary Activities Implemented by Respondents (n=150).

Type of Activity	Response frequency (n=150)*	
	n	**n**
Group/Collaborative Work	86	57.3
Visits to museums, science centers, or natural spaces	70	46.7
Project work	58	38.7
Use of digital and technological tools	52	34.7
Field practical activities	44	29.3
Laboratory practical activities	41	27.3
Experimental practical activities	38	25.3
Thematic interdisciplinary discussions or debates	30	20.0
Others	1 mention	0.7

** Participants could select more than one option; therefore, total mentions exceed the number of respondents. Percentages were calculated based on the total number of participants.*

Other common activities included *Project Work* (n=58; 38.7%) and the *Use of digital and technological tools* (n=52; 34.7%), reflecting efforts to integrate inquiry-based and technology-enhanced practices. Less frequently reported were *Field practical activities* (n=44; 29.3%), *Laboratory practical activities* (n=41; 27.3%), and *Experimental practical activities* (n=38; 25.3%), which, while relevant, may require logistical resources not always available. *Thematic interdisciplinary discussions or debates* were mentioned by a smaller portion of respondents (n=30; 20.0%), and *Other* types of activities were rarely cited (n=1; 0.7%). These findings suggest that teachers tend to favour collaborative and experiential learning strategies, often complemented by partnerships with informal science education institutions.

Overall, teachers demonstrated a strong appreciation for interdisciplinary teaching. On a 5-point Likert scale, participants expressed high levels of agreement with several pedagogical benefits associated with interdisciplinarity. Descriptive statistics are summarised in Table 5.

Table 5. Average Responses to **Q6** of Questionnaire: Perceptions of Interdisciplinarity in Science Education (n=150).

Affirmations	Mean (n=150)
Interdisciplinarity contributes to a better understanding of scientific concepts.	4.51
Interdisciplinary practices promote the development of students' transversal skills.	4.66
The integration of different disciplinary areas in teaching promotes a more attractive and motivating science learning.	4.47
Interdisciplinary teaching stimulates critical and creative thinking in students.	4.55
Interdisciplinary teaching stimulates students' reasoning and problem-solving skills.	4.56
Interdisciplinary work allows addressing complex problems in a more integrated way.	4.51
Interdisciplinary practices help students develop a more holistic view of knowledge.	4.57
The articulation between disciplines in science teaching facilitates the learning of abstract concepts.	4.35
Interdisciplinarity in science teaching is an important approach to prepare students for ongoing global changes.	4.48
The interdisciplinary approach in science can allow the integration of non-scientific areas,	4.43

fostering connections with cultural, social, and artistic contexts.

The highest-rated statement was that it promotes the development of students’ transversal skills (M=4.66), followed closely by its contribution to a more holistic understanding of knowledge (M=4.57) and the stimulation of reasoning and problem-solving skills (M=4.56). Participants also strongly agreed that it fosters critical and creative thinking (M=4.55), supports a more attractive and motivating learning experience (M=4.47), and contributes to a better understanding of scientific concepts (M=4.51). Furthermore, interdisciplinarity was perceived as enabling the integration of complex real-world problems (M=4.51), supporting the articulation between scientific disciplines to facilitate the learning of abstract concepts (M=4.35), and preparing students for ongoing global changes (M=4.48). The statement “The interdisciplinary approach in science can allow the integration of non-scientific areas, fostering connections with cultural, social, and artistic contexts” also received a high level of agreement (M=4.43), indicating openness to transdisciplinary approaches.

4. Discussion

The analysis shows a strong consensus among participants on the pedagogical value of interdisciplinarity in science education. Teachers highlighted its relevance for enhancing student motivation, improving conceptual understanding, and developing transversal competencies, holistic thinking, and problem-solving skills. These views reflect a clear alignment between interdisciplinary practices and educational goals focused on meaningful, contextualized learning. Most participants reported engaging in interdisciplinary teaching, though this tends to happen more sporadically than systematically. While interdisciplinarity is valued, its consistent implementation remains limited. Environmental and sustainability-related themes, such as sustainability, biodiversity, and climate change, were among the most addressed topics. In contrast, historical, mathematical, and artistic perspectives were less frequently explored. Teachers preferred participatory and experiential strategies, such as group work, visits to museums or science centres, and project-based learning. Laboratory activities and interdisciplinary debates were less commonly used. Despite positive perceptions, several persistent challenges were identified. Teachers reported limited teaching and planning time, lack of educational resources, and insufficient training for applying interdisciplinary approaches. Institutional constraints and few opportunities for professional development in non-formal education settings were also noted. Overall, the findings highlight a gap between the conceptual support for interdisciplinarity and the conditions necessary for its sustained and systematic implementation. Teachers expressed a clear need for targeted professional development and greater institutional flexibility to support collaborative interdisciplinary practices.

These findings confirm previous research indicating that, although educators recognise the value of interdisciplinary practices, their consistent implementation is hindered by factors such as limited time, institutional rigidity, and inadequate preparation [7,9,10]. Teachers generally align pedagogically with interdisciplinarity’s goals, particularly in promoting holistic learning and transversal competencies. However, systemic barriers prevent these intentions from being fully realised in practice. The current Portuguese educational framework, while progressing, still lacks effective mechanisms to support interdisciplinary planning, including joint planning time, curricular flexibility, and cross-department collaboration. Moreover, museums and other non-formal educational environments offer significant opportunities to complement traditional classroom-based interdisciplinary teaching. As highlighted in the literature, partnerships with museums, science centres, and similar institutions can greatly enhance teachers' ability to integrate real-world, cross-disciplinary learning experiences. These settings, when integrated with formal education, provide unique resources and professional development opportunities that strengthen interdisciplinary practices. Teachers can benefit from access to specialized content, experiential learning, and collaborative partnerships that enrich their teaching [11,12].

5. Conclusion

For interdisciplinary science education to thrive, it requires more than motivated teachers. It demands supportive institutional frameworks and sustained professional development focused on experiential and collaborative pedagogies. Policymakers and school leaders must prioritise creating structural conditions that encourage collaboration, allocate sufficient time for planning, and provide ongoing training aligned with interdisciplinary approaches. The findings of this study provide a detailed portrait of Portuguese science teachers' perceptions, practices, and the challenges they face in implementing interdisciplinarity. The results reveal a strong recognition of the educational benefits of interdisciplinary approaches, particularly in promoting critical thinking and engaging students with real-world problems. However, systemic barriers continue to impede their consistent application. Strategic and coordinated interventions are therefore essential. Without addressing the structural and institutional constraints identified, interdisciplinarity will remain a valued yet inconsistently realised principle. Ensuring the necessary support structures is crucial to transforming interdisciplinary science education from an aspiration into a sustained and effective pedagogical practice. Thematic analysis showed that topics related to biodiversity, climate change, and water management dominate the interdisciplinary agenda, reflecting a clear orientation toward ecological and societal relevance. In contrast, themes connected to the history and philosophy of science, as well as mathematical-artistic intersections, such as the golden ratio, are rarely addressed. These highlights missed opportunities for broader and more creative interdisciplinary integration. These less explored areas represent valuable possibilities for future development through targeted strategies and innovative resources.

REFERENCES

[1] Pombo O., "Signs of interdisciplinarity in the second half of the XX century and prospects for the XXI century", Theory and practice in the interdisciplinary production and reproduction of scientific knowledge: ID in the XXI Century, Springer International Publishing, 2023, pp. 241–299. https://doi.org/10.1007/978-3-031-20405-0_13

[2] Teles N., Ribeiro T., Vasconcelos C., "Exploring the golden ratio in nature by using a STEAM approach: A diagnostic and quasi-experimental study at a senior university", Education Sciences, 2024, 14(7), 705. https://doi.org/10.3390/educsci14070705

[3] De Melo A., Caves L., "Complex Systems of Knowledge Integration: A Pragmatic Proposal for Coordinating and Enhancing Inter/Transdisciplinarity", From Astrophysics to Unconventional Computation, 2019. https://doi.org/10.1007/978-3-030-15792-0_14

[4] Shanableh A., Aderibigbe S., Omar M., Shabib A., "Challenges and Opportunities of Multi-Disciplinary, Inter-Disciplinary and Trans-Disciplinary Research", Higher Education in the Arab World: Research and Development, 2022. https://doi.org/10.1007/978-3-030-80122-9_18

[5] Kaynar H., Kurnaz A., "The effect of interdisciplinary teaching approach on the creative and critical thinking skills of gifted pupils", Thinking Skills and Creativity, 2024. https://doi.org/10.1016/j.tsc.2024.101637

[6] Ye P., Xu X., "A case study of interdisciplinary thematic learning curriculum to cultivate '4C skills'", Frontiers in Psychology, 2023, 14. https://doi.org/10.3389/fpsyg.2023.1080811

[7] Darling-Hammond L., Hyler M. E., Gardner M., "Effective teacher professional development", Learning Policy Institute, 2017. https://learningpolicyinstitute.org/product/effective-teacher-professional-development-report

[8] Ministério da Educação, "Perfil dos Alunos à Saída da Escolaridade Obrigatória", República Portuguesa, 2017. https://www.dge.mec.pt/perfil-dos-alunos-saida-escolaridade-obrigatoria

[9] Lesseig K., Nelson T., Slavit D., Seidel R., "Supporting Middle School Teachers' Implementation of STEM Design Challenges", School Science and Mathematics, 2016, 116, pp. 177–188. https://doi.org/10.1111/SSM.12172

[10] Li J., "Effective Strategies for Interdisciplinary Integration in STEAM Curriculum Design", Transactions on Social Science, Education and Humanities Research, 2024. https://doi.org/10.62051/gvesha87

[11] Sukhomlynova O., Lysenko T., Rembach O., Pavelko V., Kovalchuk Y., "Implementing interdisciplinary methods in the educational framework", Cadernos de Educação Tecnologia e Sociedade, 2024. https://doi.org/10.14571/brajets.v17.nse3.61-72

[12] Kanmaz A., “A study on interdisciplinary teaching practices: Primary and secondary education curricula”, African Educational Research Journal, 2022. https://doi.org/10.30918/aerj.102.22.032

APPENDIX 1. Data collection instrument

Question	Options
Q1. Have you participated or do you participate in interdisciplinary activities?	Yes; No
Q2.1. Indicate the discipline(s) (other than your own) with which you have developed interdisciplinary activities.	Biology; Physics; Geology; Mathematics; Chemistry
Q2. How often do you integrate content from other disciplines not explicitly included in your subject’s curriculum?	Never; Rarely; Sometimes; Frequently; Very frequently
Q3. What are the main barriers to implementing interdisciplinary activities in schools? (Select all that apply)	Lack of available teaching time; Lack of physical spaces; Lack of planning time; Lack of student interest; Lack of teacher interest; Lack of specific training; Lack of educational resources; Lack of funding; Institutional constraints; Lack of training opportunities in non-formal education; Other (specify)
Q4. Which of the following topics have you addressed interdisciplinarily? (Select all that apply)	Golden Ratio and Fibonacci Sequence; Sustainability and Biodiversity; Biotechnology and Environment; Climate Change and Environmental Impacts; Scientific Technologies and Innovations; History and Nature of Science; Energy and Sustainability; Health and Science; Science and Society; Space Exploration; Food and Sustainability; Water: Essential Resource; Geosciences and Natural Disasters; Sustainable Cities; Science and Technology in Everyday Life; Other (specify)
Q5. What types of interdisciplinary activities do you usually implement? (Select all that apply)	Project work; Group/Collaborative work; Laboratory practical activities; Experimental activities; Fieldwork activities; Visits to museums/science centres/natural spaces; Use of digital and technological tools; Interdisciplinary thematic debates; Other (specify)
Q6. 5-point Likert Scale	a) Interdisciplinarity contributes to a better understanding of scientific concepts. b) Interdisciplinary practices promote the development of students’ transversal skills. c) The integration of different disciplinary areas in teaching promotes a more attractive and motivating science learning. d) Interdisciplinary teaching stimulates critical and creative thinking in students. e) Interdisciplinary teaching stimulates students’ reasoning and problem-solving skills. f) Interdisciplinary work allows addressing complex problems in a more integrated way. g) Interdisciplinary practices help students develop a more holistic view of knowledge. h) The articulation between disciplines in science teaching facilitates the learning of abstract concepts. i) Interdisciplinarity in science teaching is an important approach to prepare students for ongoing global changes. j) The interdisciplinary approach in science can allow the integration

	of non-scientific areas, fostering connections with cultural, social, and artistic contexts.