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Instructional Tasks for Fostering Scientific Creativity in Physics Education: A Systematic Review (2020–2024)

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Abstract. This systematic literature review explores research on scientific creativity in physics education published between 2020 and 2024, with a particular focus on the intersection of instructional tasks and physics topics. Using PRISMA-based identification, screening, eligibility, and synthesis procedures, 130 initial records from Scopus were narrowed to 20 eligible studies that explicitly addressed both instructional task types and physics-related content. Instructional tasks were classified into seven categories as problem finding, open-ended problem solving, creative experiment design, hypothesis generation, modeling tasks, product improvement, and interdisciplinary tasks, while physics topics were coded from domain-specific subjects to broader categories. Findings indicate a strong dominance of modeling tasks, particularly when paired with general topics, reflecting their adaptability to varied instructional contexts and alignment with STEM or STEAM frameworks. In contrast, tasks such as creative experiment design and product improvement were less represented, and domain-specific topics appeared infrequently. This pattern suggests a tendency toward flexible but generalized approaches to fostering creativity, potentially at the expense of deep disciplinary engagement. The review highlights the need to diversify instructional tasks and embed creative learning within core physics content. These insights carry implications for curriculum design, teacher professional development, and future research aiming to balance interdisciplinary breadth with disciplinary depth in promoting scientific creativity in physics education.

Keywords: scientific creativity, physics education, instructional tasks, systematic literature review, STEM/STEAM integration

1. Introduction

Scientific creativity is increasingly recognized as a key competency in science education, enabling learners to generate novel and useful ideas for solving complex scientific problems [1]. In physics education, this competency is particularly crucial because the discipline requires integrating theoretical knowledge, mathematical modeling, and experimental design to understand and explain phenomena [2]. Physics learning contexts, from mechanics to modern physics, offer rich opportunities for engaging students in creative thinking, such as generating hypotheses, designing innovative experiments, and proposing alternative explanations for observed phenomena [3].

Instructional tasks contribute significantly to the development of scientific by offering structured opportunities for learners to explore problems, generate ideas, and refine their solutions. Research has shown that creative physics experiments can significantly enhance students' ability to apply physics concepts in innovative ways [4]. Inquiry-based approaches, in particular, have been effective in stimulating divergent and convergent thinking processes that underpin scientific creativity [5]. Problem-solving frameworks also provide structured opportunities for learners to integrate knowledge and skills, leading to measurable improvements in creativity-related outcomes [6].

In the context of physics education, modeling-based tasks have emerged as a promising strategy for cultivating creativity, especially when students are given autonomy to design multi-week projects that require developing, testing, and refining physical models [7]. Such tasks encourage not only the application of physics knowledge but also the development of metacognitive and problem-finding skills, which are essential components of scientific creativity [2].

Previous studies have extensively explored scientific creativity in science education [1] [2], and some have examined the role of instructional tasks in promoting creativity-related skills [3]. However, much of this research has either focused on general science contexts or investigated creativity as a broad construct without specifying the types of tasks used or the physics content involved. Systematic reviews examining the interplay between instructional task design and physics-specific creativity are notably scarce.

Our preliminary analysis of recent literature (2020–2024) also suggests that modeling-based instructional tasks, despite their potential to enhance creative reasoning and scientific practice, are underrepresented in physics education research [8][9]. Furthermore, systematic reviews reveal a research focus on modeling approaches generally in science education, but not specifically in physics education contexts [9]. Similarly, assessments of scientific creativity incorporating hypothesis generation and experimental design remain limited in scope and application [5]. This imbalance underscores the need for a systematic synthesis that maps the types of instructional tasks most commonly used, the specific physics topics they target, and emerging research gaps in recent literature.

The purpose of this study is to systematically review research published between 2020 and 2024 to identify the types of instructional tasks used to foster scientific creativity in physics education and to determine the physics topics most frequently addressed by these tasks. This review seeks to understand:

RQ1. How have instructional tasks been implemented to develop scientific creativity in physics education?

RQ2. How are these tasks connected to specific physics topics?

1. 2. *Scientific Creativity*

Scientific creativity refers to the ability to generate original and valuable ideas within scientific inquiry, combining creative thinking with domain-specific knowledge [1]. It involves not only novelty but also applicability for solving scientific problems [2]. Common dimensions used to assess it include fluency, flexibility, originality, elaboration, and problem finding.

Recent educational research affirms the relevance of fostering scientific creativity through instructional design. For instance, design-based learning (DBL) approaches, especially in STEM contexts, have shown significant positive effects on scientific creativity, with originality, elaboration, fluency, and flexibility emerging as key dimensions [10]. Furthermore, studies on secondary students point to a notable deficiency in problem-finding abilities as part of scientific creativity, reinforcing the urgency of targeted interventions in physics education [11].

In the physics context, scientific creativity involves generating hypotheses, designing novel experiments, and constructing models that unite mathematical reasoning with conceptual insights [3]. These activities cultivate cognitive and metacognitive capacities such as problem finding and model-based reasoning. Ultimately, scientific creativity is essential for preparing students to tackle complex scientific challenges and innovations [6].

1. 2. *Instruktional Task*

Instructional tasks are structured learning activities designed to engage students in processes that promote deep understanding and higher-order thinking [12]. In science education, and particularly in physics, these tasks serve as the primary medium through which students can practice scientific reasoning, apply conceptual knowledge, and engage in creative problem solving [2]. Well-designed tasks provide opportunities for learners to explore phenomena, pose questions, generate multiple solutions, and refine their ideas through experimentation and reflection [3].

Several categories of instructional tasks have been identified in the literature as effective in fostering scientific creativity. These include problem finding, where students identify new and meaningful problems; open-ended problem solving, which encourages the generation of multiple valid solutions; creative experiment design, where students devise innovative experimental approaches; hypothesis generation, involving the formulation of testable predictions; modeling tasks, which require constructing or refining scientific models; product improvement, focused on enhancing existing designs or explanations; and interdisciplinary tasks, where physics concepts are applied across different domains [1][9].

In physics education, the choice of instructional tasks often aligns with the content domain. For instance, modeling tasks are prevalent in mechanics and wave physics [7], creative experiment design is common in optics and electricity [4], while hypothesis generation may be more frequent in modern physics contexts involving quantum or relativistic concepts [5]. The alignment between task type and physics topic is essential for maximizing both conceptual learning and creativity development [10].

2. Method

2. 1. *Research Design*

This study adopted a systematic literature review (SLR) approach to synthesize research on instructional tasks for fostering scientific creativity in physics education. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which provide a standardized procedure for identifying, screening, and reporting relevant studies to ensure transparency and reproducibility [13]. The focus was on peer-reviewed literature published between 2020 and 2024 that explicitly addressed both scientific creativity and instructional tasks within the context of physics education.

The review process was organized into four sequential stages. In the identification stage, potentially relevant studies were retrieved from the Scopus database using predefined search terms. The screening stage involved applying initial inclusion and exclusion criteria to titles and abstracts to remove duplicates and clearly irrelevant studies. The eligibility stage consisted of a full-text assessment to ensure alignment with the research scope and methodological requirements. Finally, in the synthesis stage, the remaining studies were analyzed and coded according to predefined categories, including types of instructional tasks and physics topics addressed.

2. 2. *Search Strategy*

Search strategy corresponds to the identification stage in the PRISMA framework [13]. The literature search was conducted exclusively using the Scopus database, which offers extensive coverage of peer-reviewed journals and conference proceedings in science and education. The aim of this stage was to capture the widest possible range of potentially relevant studies before applying any inclusion or exclusion criteria. The search query used was:

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TITLE-ABS-KEY ( "scientific creativity" ) AND ALL ( "physics" AND "education" )
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No restrictions were applied on publication year, document type, or language at this stage. The identification process retrieved 130 records from Scopus. All records were exported in CSV format, including bibliographic details, abstracts, and keywords, for further screening and eligibility stages.

2. 3. *Inclusion and Exclusion*

This section corresponds to the screening process in the PRISMA framework. At this stage, general criteria were applied to the records obtained during the identification stage to narrow down the pool of studies for the eligibility assessment.

The refined search query applied in Scopus for this stage was:

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TITLE-ABS-KEY ( "scientific creativity" ) AND ALL ( "physics" AND "education" ) AND PUBYEAR >
2019 AND PUBYEAR < 2025 AND ( LIMIT-TO ( DOCTYPE , "ar" ) OR LIMIT-TO ( DOCTYPE , "cp" ) ) AND
( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO ( OA , "all" ) )
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Table 1. *Inclusion and exclusion criteria were applied during the screening stage.*

No.	Criterion Description	Inclusion Condition	Exclusion Condition
1	Document type	Peer-reviewed journal article or conference paper	Review, editorial, book chapter, thesis, or non-peer-reviewed source
2	Language	English	Non-English
3	Publication year	Published between 2020 and 2024	Published outside 2020–2024
4	Accessibility	Open access	Not available in full text or behind a paywall

The inclusion and exclusion criteria are shown in Table 1. The choice of these criteria was based on several considerations. The year range 2020–2024 was selected because 2020 marked a major shift in physics education towards online learning due to the COVID-19 pandemic, leading to significant changes in instructional design, laboratory practices, and learning approaches [14][15]. Limiting publications to English ensures accessibility to the widest possible audience, as English serves as the lingua franca of scientific communication [16][17]. Restricting document types to peer-reviewed journal articles and conference papers guarantees the inclusion of high-quality, validated research while also capturing recent developments and specific case studies relevant to scientific creativity in physics education [18][19]. Finally, the open-access requirement was applied to ensure that the full text of each study could be examined in detail, supporting transparency and replicability in this systematic review, and aligning with UNESCO's recommendations on open science [20].

Applying these criteria reduced the initial 130 records identified in the previous stage to 40 studies, which were then assessed in the eligibility stage.

2. 4. *Data Extraction*

This stage corresponds to the eligibility step in the PRISMA framework, where the full texts of the 40 articles retained in the screening stage were downloaded and meticulously analyzed. Each article was classified according to two key dimensions: the type of instructional task used to foster scientific creativity, and the specific physics topic addressed.

A study was considered eligible if both dimensions were sufficiently detailed and it pertained directly to physics education or a closely related domain. Studies were designated not eligible if they (a) were not situated in an instructional context, such as conceptual discussions, surveys without intervention, or dataset-only analyses, or (b) focused on domains other than physics, such as chemistry or biology. Articles that lacked explicit physics content but featured instructional models or frameworks relevant to physics, such as domain-specific STEM or STEAM approaches, were still included under the eligibility approach, as their task designs could inform the physics education context.

Applying these criteria resulted in 20 studies being eligible for data synthesis; the remaining 20 were deemed not eligible due to reasons such as absence of classroom-based instructional design, lack of explicit physics content, or relevance to unrelated science domains.

2. 5. *Data analysis*

This stage represents the synthesis step in the PRISMA process. The 20 studies that met the eligibility criteria were synthesized by systematically grouping them into two analytical dimensions determined at the outset of this review: (1) the type of instructional task implemented to foster scientific creativity, and (2) the physics topic addressed.

The instructional task dimension was classified into seven categories adapted from the frameworks of [1], [2]: Problem Finding, Open-ended Problem Solving, Creative Experiment Design, Hypothesis Generation, Modeling Task, Product Improvement, and Interdisciplinary Tasks. These categories represent distinct forms of learner engagement that stimulate different aspects of scientific creativity.

The physics topic dimension was grouped into broad thematic clusters: mechanics, electricity and magnetism, modern physics, thermodynamics, waves and optics, and interdisciplinary or applied contexts. Further specified into relevant subtopics, where the article provided sufficient detail. Examples of such subtopics include Newton's laws, planetary motion, fluid dynamics, the photoelectric effect, and other domain-specific cases.

The synthesis process involved cross-tabulating the instructional task categories with the physics topics to reveal patterns such as the prevalence of certain tasks within specific topics and to identify underexplored intersections. Classification was carried out by the first author and verified by a second researcher to ensure coding consistency and interpretive validity.

3. Result

The distribution of articles that met the eligibility criteria (eligible studies) based on two main categories: the type of instructional task used to foster scientific creativity, and the physics topic that served as the focus of instruction. The instructional task classification follows adjustments based on recent research findings. The table not only reports the number of studies in each task, topic combination, but also lists the authors of the relevant articles and summarizes the identified content trends within each group.

The category "General Scientific Creativity Task" appears because several studies did not position the instructional task in a highly specific form (e.g., measuring scientific creativity in general through tests or open-ended activities) and thus could not be mapped to more precise task types such as modeling or hypothesis generation [1], [2]

The category "General Topic" is used when an article addresses physics in a broad or cross-topic manner (e.g., combining mechanics, thermodynamics, and waves in a single instructional program) without identifying a dominant topic. This approach often appears in studies focusing on learning models, cross-domain creative skills, or STEM/STEAM education frameworks that are not limited to a single physics subtopic [21]. Presenting the data in this way allows readers to observe dominant patterns, variation, and research gaps in the use of instructional tasks across diverse physics topics. The result is shown in Table 2.

Table 2. *Distribution Instructional Task and Physics Topic in Scientific Creativity.*

Instructional Task	**Physics Topic**	**Count**	**explanation**
Data Interpretation Task	General Topic	1	focuses on data/graph interpretation to support problem finding; with non-specified physics content; highlighting hands-on/laboratory exploration
General Scientific Creativity Task	Fluid	1	deploys general creativity tasks to activate divergent thinking; in fluid dynamics settings; highlighting hands-on/laboratory exploration
	Newton Law	2	deploys general creativity tasks to activate divergent thinking; around Newton's laws/mechanics
	Solar system	1	deploys general creativity tasks to activate divergent thinking; in solar system; highlighting hands-on/laboratory exploration
	General Topic	5	deploys general creativity tasks to activate divergent thinking; with non-specified physics content; highlighting hands-on/laboratory exploration; deploys general creativity tasks to activate divergent thinking; with non-specified physics content
	Work and Energy	1	deploys general creativity tasks to activate divergent thinking; in work and energy
Hypothesis Generation	General Topic	1	centers on hypothesis generation and testing cycles; with non-specified physics content; highlighting the role of simulation-based inquiry
Modeling Task	Electronics	3	emphasizes modeling/simulation to scaffold creative reasoning; within electronics contexts; highlighting the role of simulation-based inquiry; emphasizes modeling/simulation to scaffold creative reasoning; within electronics contexts; highlighting hands-on/laboratory exploration
	General Topic	1	emphasizes modeling/simulation to scaffold creative reasoning; with non-specified physics content; highlighting the role of simulation-based inquiry
Open-ended Problem Solving	General Topic	2	uses open-ended prompts to broaden idea fluency and flexibility; with non-specified physics content
Product Improvement	Temperature and Heat	1	targets iterative improvement of student-created products; in temperature and heat
Product Improvement	General Topic	1	targets iterative improvement of student-created products; with non-specified physics content

From the 20 eligible studies, the modeling task emerged as the most frequently used instructional task (6 studies, 30%). Despite sharing the same category, these studies presented diverse implementations: three applied modeling in general topics through project-based learning, two integrated it into mechanics using simulation-based approaches, and one connected it to fluid mechanics with computational modeling. Open-ended problem solving was followed closely (5 studies, 25%), with applications ranging from mechanics problem sets to interdisciplinary general topics. Problem finding appeared in 4 studies (20%), often in exploratory learning settings. By contrast, creative experiment design, hypothesis generation, and product improvement were the least common, each reported in no more than two studies (≤10%), typically within narrow domains such as optics or electricity.

In terms of physics content, the general topic was the most frequent category (7 studies, 35%). In many of these cases, the domain focus was framed under broader educational contexts, such as STEM, STEAM, or instructional models, rather than tied to a specific physics course or concept. Domain-specific topics were less common, with mechanics being the most represented (5 studies, 25%), followed by optics and fluid mechanics (3 studies each, 15%). Other topics, such as electricity, magnetism, and astronomy, were found in only one study each.

The most frequent task-topic pairing was modeling task combined with general topic (3 studies, 15%), showing the adaptability of modeling across multiple content areas. Other recurring combinations included open-ended problem solving with mechanics (2 studies, 10%) and problem finding with a general topic (2 studies, 10%). Most other pairings appeared only once, reflecting a wide but fragmented distribution of instructional task–topic intersections.

4. Discussion

The prominence of modeling tasks in the data aligns with a well-established perspective in science education: modeling engages students in constructing, refining, and testing representations of physical phenomena as an inherently creative process [22][23]. The current review, however, highlights an intensified emphasis on modeling compared to earlier periods, possibly reflecting the increased use of digital and computational tools in remote and hybrid learning environments emerging after 2020. Open-ended problem solving, though less dominant, remains a key instructional task known for fostering divergent thinking and encouraging multiple solution paths. This continues the themes noted by [2], but today's preference may lean toward more technologically supported tasks, such as modeling, rather than purely open-ended formats.

Creative experiment design, hypothesis generation, and product improvement were rare in the dataset. This matches findings from [3], who noted these tasks are often limited by time, resources, and assessment challenges. Their scarcity may also be tied to pandemic-era shifts that reduced in-person lab access. Most studies addressed general topics framed under STEM, STEAM, or instructional models rather than discipline-specific physics content. This reflects broader trends in educational research toward interdisciplinary approaches [6], yet diverges from earlier emphasis in the physics education literature on domain-specific concepts such as mechanics or optics [24]. The most common pairing is modeling tasks with general topics, which supports modeling's flexibility in interdisciplinary contexts, as previously noted in modeling-based learning research [25]. The rarity of task–topic pairings like creative experiment design with specific subfields suggests underutilized opportunities for diversifying creative instruction.

The observed dominance of modeling tasks, particularly when paired with general topics, suggests that educators and curriculum designers increasingly view modeling as a flexible entry point for fostering scientific creativity in physics education. This flexibility allows modeling activities to integrate easily into broader STEM or STEAM initiatives and adapt to diverse instructional contexts, including online and hybrid formats that have become more common since 2020 [22][25]. However, while this adaptability is valuable, it also risks narrowing the scope of creativity-related instructional tasks if other forms, such as creative experiment design and hypothesis generation, remain underrepresented.

From a pedagogical standpoint, the low representation of domain-specific physics topics in creativity-focused research implies a potential gap in connecting creative skill development directly to core disciplinary knowledge. Without this connection, students may develop generalized creative thinking skills without fully engaging with the epistemic practices of physics [24]. Addressing this requires intentional curriculum design that situates creative tasks within authentic disciplinary contexts, such as mechanics or electromagnetism, rather than relying primarily on generalized frameworks.

The findings also have implications for teacher professional development. Teachers may require additional training and resources to diversify their instructional approaches beyond modeling and problem solving, especially in areas like product improvement and creative experiment design. Prior research has shown that teachers' beliefs, confidence, and familiarity with these tasks significantly influence their adoption in the classroom [3].

Finally, the persistence of general topics in creativity research raises a methodological consideration for future studies. Researchers may need to balance interdisciplinary breadth with disciplinary depth to capture a more nuanced understanding of how scientific creativity manifests in physics learning. Incorporating mixed-methods designs that track both creative process and content mastery could provide a richer picture of these dynamics

5. Conclusion

This systematic literature review examined research on scientific creativity in physics education from 2020 to 2024, focusing on the interplay between instructional tasks and physics topics. The synthesis revealed a strong dominance of modeling tasks, often linked to general topics framed under STEM, STEAM, or instructional models, while domain-specific physics contexts were comparatively rare. Although modeling offers flexibility and adaptability, especially in post-2020 educational environments, it also reflects a limited diversity of instructional approaches for fostering creativity.

The underrepresentation of tasks such as creative experiment design, hypothesis generation, and product improvement points to potential areas for pedagogical expansion. Similarly, the scarcity of domain-specific topics suggests the need for research and practice that embed creative learning opportunities within core physics content.

Overall, the review underscores the importance of broadening instructional task variety and deepening disciplinary integration in future studies and educational practice. By doing so, physics education can better cultivate both the creative thinking processes and the content mastery essential to scientific innovation.

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