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An Inductive Typology of Artificial Intelligence Use in Science Teaching and Its Alignment with AI Literacy Frameworks

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Systematic Review

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Abstract

Artificial intelligence (AI) is increasingly discussed as a transformative force in education, yet limited attention has been devoted to systematically examining how AI is represented as being used by teachers in subject-specific contexts. This study provides an empirically grounded classification of AI use in science education based on the analysis of 795 Scopus-indexed journal articles. Using a qualitative, document-based approach, abstracts were analyzed inductively to identify recurring pedagogical functions attributed to AI in science teaching. Six non-exclusive categories emerged: instructional delivery and pedagogy, assessment and feedback, lesson planning and curriculum design, interactive agents, simulations and virtual environments, and teacher professional development and support. In a second analytical stage, these categories were interpreted through the OECD AI Literacy Framework to examine how documented practices align with broader domains of AI engagement. The findings indicate that AI is predominantly framed as supporting classroom interaction and assessment processes, with strong alignment to engagement-oriented and design-mediated modes of AI use. Overall, the literature positions teachers as pedagogical integrators who interpret and structure AI within existing instructional practices rather than as technical developers. The study contributes a large-scale, practice-oriented typology of AI use in science education and offers an analytically grounded bridge between empirical representations and AI literacy discourse.

1. Introduction

Artificial intelligence has rapidly moved from a speculative technological horizon to an increasingly embedded presence within educational discourse and practice. Across policy documents, research publications, and institutional strategies, AI is frequently portrayed as a transformative force capable of reshaping teaching, learning, and assessment. Yet, despite the proliferation of AI-related tools and the intensification of debate surrounding their implications, there remains considerable ambiguity regarding how AI is actually integrated into everyday educational practice, particularly at the level of subject teaching. Discussions often emphasize potential, innovation, or systemic reform, while comparatively less attention is devoted to understanding how teachers operationalize AI within their pedagogical routines (UNESCO, 2021; U.S. Department of Education, 2023; Garzón et al., 2025).

This ambiguity becomes especially salient within science education, a domain characterized by distinctive epistemic practices such as inquiry, modelling, experimentation, and evidence-based reasoning. The integration of new technologies into science teaching is rarely neutral; it interacts with disciplinary content, representational forms, and pedagogical traditions. Artificial intelligence, with its capacity for adaptive feedback, generative content production, simulation, and data-driven decision support, introduces additional layers of complexity. Whether AI reinforces established instructional structures or enables new modes of disciplinary engagement depends largely on how it is interpreted and enacted by teachers within specific educational contexts (Lee et al., 2025; Petko et al., 2025).

At the same time, the expanding body of research on AI in education presents a paradox. On the one hand, bibliometric analyses and systematic reviews document a rapidly growing research landscape. On the other hand, much of this literature remains fragmented across tool-specific studies, intervention-based reports, or normative discussions of future-oriented AI integration. As a result, it is difficult to obtain a coherent, practice-oriented overview of how AI use by teachers is currently conceptualized in science education research. Without such an overview, both theoretical discussions of AI literacy and practical debates about teacher education risk proceeding without a clear understanding of the patterns already emerging in published scholarship (Bagiani, 2025; Nikolinakos, 2023; Crawford, 2025).

Furthermore, while AI literacy frameworks and policy models provide valuable conceptual vocabularies for describing engagement with AI, they do not in themselves clarify how AI is being positioned within disciplinary teaching practice. Frameworks articulate domains of engagement, competence, or responsibility, but the empirical question of how teachers use AI within science classrooms and preparatory work remains insufficiently systematized. Bridging this gap requires an approach that is grounded in the analysis of documented practice, yet capable of connecting such analysis to broader conceptual structures without imposing them prematurely (Chee et al., 2025; OECD, 2025).

Against this backdrop, the present study seeks to provide a systematic and empirically grounded classification of how artificial intelligence is represented as being used by teachers in science education. Drawing on a large corpus of Scopus-indexed publications, the study develops an inductive typology of AI use based on recurring pedagogical functions described in the literature. In a second analytical stage, these empirically derived categories are interpreted through the lens of an established AI literacy framework, allowing for a structured examination of how documented practices align with broader modes of AI-related engagement. By separating category development from conceptual alignment, the study aims to contribute both descriptive clarity and theoretical integration.

By clarifying how AI use is currently framed within science education research, this study contributes to ongoing discussions concerning teacher agency, pedagogical design, and AI literacy in subject-specific contexts. Rather than asking whether AI should be integrated into education, the study addresses a more foundational question: how is AI already being positioned within science teaching as represented in academic discourse? Answering this question is essential for informing future research, guiding teacher education initiatives, and grounding policy discussions in a clearer understanding of the existing research landscape (Petko et al., 2025; Chee et al., 2025).

2. Literature review

2.1 Artificial Intelligence in the General Education Context

Artificial intelligence (AI) has increasingly been positioned as a transformative technology in education, influencing key aspects of teaching, learning, and assessment. Policy-oriented and conceptual texts describe AI as a broad set of computational systems capable of supporting educational processes

through automation, adaptation, and data-informed decision making. In educational settings, AI-related applications range from adaptive learning environments and intelligent tutoring systems to automated assessment and feedback tools and generative technologies that assist with instructional preparation. Rather than representing a single pedagogical approach, AI is presented as a flexible technological infrastructure whose educational significance depends largely on how it is embedded within teaching practices and institutional contexts (UNESCO, 2021; U.S. Department of Education, 2023; Biagini, 2025).

At the same time, the literature emphasizes that the integration of AI into education is neither uniform nor pedagogically self-evident. While AI is often associated with enhanced personalization and efficiency, several authors caution that its educational value cannot be assumed independently of teachers' professional judgment and instructional goals. As a result, AI in education is frequently discussed in terms of anticipated potential rather than systematically documented practice. This has led to calls for empirical and analytical work that examine how AI is actually taken up, interpreted, and enacted within teaching processes, rather than focusing solely on technological capabilities or projected outcomes (Li et al., 2025; Lee et al., 2025).

A further distinction emerging in the literature concerns the difference between *learning with AI* and *learning about AI*. Learning *with* AI refers to the use of AI systems as tools that support teaching and learning across subject areas, whereas learning *about* AI involves the development of knowledge and understanding of AI concepts, systems, and implications. Although both orientations are increasingly visible in educational discourse, they serve different analytical purposes. The present study is concerned exclusively with learning *with* AI, and more specifically with how AI is employed by teachers as part of their instructional, planning, and assessment practices, rather than with AI as curricular content in itself.

While the broader educational literature increasingly acknowledges the transformative potential of artificial intelligence, it also makes clear that the educational significance of AI does not reside in technological systems alone. The ways in which AI is interpreted, adopted, and embedded within educational practice are shaped primarily by teachers' pedagogical intentions, professional knowledge, and contextual constraints. Consequently, understanding AI in education requires shifting analytical attention from technological affordances to the actors who make decisions about its use in classrooms. This perspective positions teachers not as passive recipients of AI-driven innovation, but as central agents whose choices determine how, and for what purposes, AI is integrated into teaching and learning processes (UNESCO, 2021; U.S. Department of Education, 2023; Petko et al., 2025).

The integration of artificial intelligence into educational practice is increasingly understood as a process mediated by teachers rather than determined by technological capabilities alone. Across contemporary educational literature, teachers are positioned as key decision-makers who interpret, adapt, and appropriate digital tools in ways that align with pedagogical aims, curricular requirements, and classroom realities. AI systems do not enter educational settings as neutral or self-directing innovations; instead, their instructional role is shaped by teachers' professional judgments regarding when, how, and for what purposes such systems should be used. This perspective foregrounds the importance of

examining AI use through the lens of teaching practice, rather than treating AI as an autonomous driver of educational change (Petko et al., 2025; Lee et al., 2025).

Recent scholarship further emphasizes that teachers' engagement with AI is influenced by a complex interplay of professional knowledge, beliefs, and contextual factors. Decisions related to AI use are embedded within broader pedagogical considerations, including instructional goals, assessment strategies, and perceptions of student needs. As a result, the same AI tool may be employed in markedly diverse ways across classrooms or educational systems. This variability challenges generalized claims about "AI in education" and instead calls for analytical approaches that capture the diversity of teacher-mediated uses. Understanding how teachers position AI within their instructional repertoires is therefore essential for developing a more nuanced account of AI integration in educational practice (Garzón et al., 2025; Nikolinakos, 2023).

Policy-oriented and research-informed documents similarly highlight the significant role of teachers in shaping the educational impact of AI. Rather than framing AI adoption as a technical implementation issue, these sources stress the need to consider teachers' agency, professional learning, and interpretive work. AI-related innovations are frequently discussed as tools that can support lesson planning, classroom instruction, assessment, and professional reflection, yet the literature also acknowledges that such uses are contingent upon teachers' capacity to integrate AI meaningfully into existing pedagogical frameworks. This recognition reinforces the view that empirical attention should be directed toward how AI is actually taken up in teaching practice, rather than toward prescriptive models of AI use (U.S. Department of Education, 2023; Biagini, 2025).

Taken together, these perspectives suggest that studying AI in education requires moving beyond tool-centered descriptions toward an examination of teachers enacted practices. By focusing on teachers as active agents who shape the role of AI within educational contexts, research can provide a clearer understanding of how AI functions within real teaching environments. This orientation is particularly relevant for subject-specific domains, such as science education, where instructional decisions are closely tied to epistemic practices, representations, and modes of inquiry. Consequently, a systematic analysis of how teachers use AI, as reflected in published research, offers an important pathway for clarifying current patterns of AI integration and identifying areas where further pedagogical and conceptual development is needed (Petko et al., 2025; Jufrida et al., 2025).

The integration of digital technologies into teaching has long been examined through conceptual frameworks designed to capture the complex relationships between pedagogy, subject matter, and technological tools. Rather than treating technology as an external addition to instruction, these frameworks emphasize that meaningful integration depends on how technological affordances are aligned with pedagogical intentions and disciplinary knowledge. Within this tradition, technology integration is understood as a situated and interpretive process shaped by teachers' professional expertise and instructional contexts, rather than as a linear progression driven by technical adoption alone (U.S. Department of Education, 2023).

One of the most influential models in this area is the Technological Pedagogical Content Knowledge (TPACK) framework, which conceptualizes teachers' knowledge as the dynamic intersection of content knowledge, pedagogical knowledge, and technological knowledge. The central contribution of TPACK lies in its emphasis on integration: effective technology use emerges not from isolated competencies, but from teachers' ability to coordinate technological possibilities with pedagogical strategies and subject-specific representations. From this perspective, technologies do not prescribe instructional practices; instead, their educational value is realized through teachers' decisions about how they support learning goals within particular disciplinary domains (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

Importantly, frameworks such as TPACK are not intended to function as taxonomies of specific tools or practices. Rather, they provide conceptual guidance for understanding *how* teachers think about and enact technology use in teaching. This distinction is particularly relevant when considering emerging technologies such as artificial intelligence, whose applications are diverse and rapidly evolving. Applying technology integration frameworks to AI does not require defining in advance what "appropriate" AI use looks like; instead, such frameworks support analytical attention to the pedagogical reasoning and contextual factors that shape teachers' engagement with AI in practice (Nikolinakos, 2023; UNESCO, 2021).

In this sense, technology integration frameworks offer a way to frame AI use in teaching as a pedagogical phenomenon rather than a technical one. They help justify an analytical focus on teachers enacted practices, while avoiding prescriptive or evaluative assumptions about technology use. For the present study, these frameworks serve to establish that understanding AI integration requires attention to the interplay between teaching goals, disciplinary content, and technological tools. However, they are not employed to classify or evaluate specific AI uses. Instead, they provide a conceptual backdrop against which empirically grounded categories of AI use can later be interpreted (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

2.2 AI Literacy and Competence Frameworks

While technology integration frameworks such as TPACK provide valuable insights into how teachers coordinate pedagogical, technological, and disciplinary knowledge, they were developed before the widespread emergence of artificial intelligence as an educational technology. As a result, they offer limited guidance for capturing the distinctive characteristics of AI, including its data-driven nature, adaptive behavior, and capacity to generate content or feedback autonomously. The growing presence of AI in educational contexts has therefore prompted the development of AI-specific literacy and competence frameworks that seek to articulate the kinds of understandings and practices required for meaningful engagement with AI in teaching and learning. These frameworks do not replace existing models of technology integration but rather extend them by addressing features of AI that raise new pedagogical, professional, and institutional considerations (Mishra & Koehler, 2006; Koehler & Mishra, 2009; Chee et al., 2025).

Building on the emergence of AI-specific concerns in education, the concept of AI literacy has gained increasing attention as a way of articulating the knowledge, skills, and practices required to engage meaningfully with AI technologies. AI literacy frameworks extend earlier notions of digital or technological literacy by focusing on the distinctive features of AI systems, such as algorithmic decision-making, data dependency, adaptivity, and the partial automation of cognitive tasks. Within educational discourse, AI literacy is not limited to technical understanding but encompasses the ability to use AI tools critically, interpret their outputs, and situate their use within pedagogical and institutional contexts. As such, AI literacy frameworks provide conceptual language for discussing what it means to engage with AI in educational practice, without prescribing specific tools or instructional strategies (Chee et al., 2025; Biagini, 2025).

A key feature of contemporary AI literacy frameworks is their emphasis on functional engagement rather than technical mastery alone. Rather than focusing exclusively on how AI systems are built, these frameworks foreground how AI is encountered, applied, and managed in real-world contexts, including educational settings. This orientation is particularly relevant for teachers, whose professional engagement with AI often involves using, adapting, or overseeing AI-supported processes rather than developing AI systems themselves. From this perspective, AI literacy frameworks offer a way to conceptualize teachers' interactions with AI that aligns with pedagogical practice and professional responsibility, while remaining sufficiently flexible to accommodate diverse educational contexts and subject domains (Chee et al., 2025; Garzón et al., 2025).

Among the existing AI literacy and competence frameworks, the OECD (2025) AI Literacy Framework provides a structured yet non-prescriptive model for understanding engagement with AI across educational and societal contexts. The framework organizes AI literacy into four broad domains: *Engaging with AI*, *Creating with AI*, *Managing with AI*, and *Designing AI*. These domains are intended to capture different modes of interaction with AI systems, ranging from use and application to oversight and development. Importantly, the OECD framework is not formulated as a curricular sequence or an evaluative hierarchy; instead, it functions as an analytical framework that can be applied across disciplines and educational levels to examine how individuals and institutions relate to AI technologies.

Within the OECD AI Literacy Framework, the four domains describe distinct but potentially overlapping modes of engagement with artificial intelligence. *Engaging with AI* refers to interacting with AI systems as users, including applying AI tools in educational activities and interpreting their outputs. *Creating with AI* involves using AI systems to generate or modify content, such as instructional materials, learning resources, or assessment artefacts, without requiring the development of AI systems themselves. *Managing with AI* encompasses overseeing, evaluating, and making decisions about AI-supported processes, including monitoring performance, interpreting feedback, and exercising professional judgment in relation to AI-generated outcomes. Finally, *Designing AI* refers to more advanced forms of engagement that involve shaping, configuring, or developing AI systems or models, including considerations related to system design, training, or adaptation. These domains are intended to function

as analytical descriptors of engagement rather than as a hierarchical progression or evaluative framework.

The functional orientation of the OECD framework makes it particularly suitable for analytical purposes in studies that seek to interpret existing practices rather than prescribe ideal forms of AI use. By focusing on modes of engagement rather than specific tools or outcomes, the framework allows for the mapping of heterogeneous practices onto a common conceptual structure. This is especially relevant in the context of science education, where AI may be employed for instructional support, assessment, simulation, planning, or professional reflection, often in overlapping ways. The OECD framework accommodates such complexity by allowing multiple domains to coexist, reflecting the multifaceted nature of teachers' interactions with AI in practice (OECD, 2025).

For the purposes of the present study, the OECD (2025) AI Literacy Framework is not used to define or delimit categories of AI use. Instead, it is employed as a second-order analytical lens that enables the interpretation of empirically identified patterns of AI use by teachers. By aligning inductively derived categories with the OECD domains, the study seeks to explore how documented uses of AI in science teaching correspond to broader conceptions of AI literacy and competence. This approach preserves the grounded nature of the initial classification while situating the findings within a policy-relevant and conceptually robust framework, thereby enhancing the interpretive depth and relevance of the analysis (Li et al., 2025; Crawford, 2025).

2.3 Methodological Positioning and Identified Research Gap

Despite the growing volume of research and policy-oriented discourse on artificial intelligence in education, the literature reveals a notable gap in systematic, practice-oriented analyses of how teachers actually use AI in their teaching. While conceptual frameworks and strategic documents articulate broad expectations regarding AI integration, they often remain at a normative or prospective level, offering limited insight into the concrete forms that AI use takes within educational practice. At the same time, existing empirical studies frequently focus on specific tools, interventions, or outcomes, making it difficult to obtain a coherent overview of the diverse ways in which AI is positioned within teaching processes across contexts. This fragmentation highlights the need for analytical approaches that synthesize published research in a way that foregrounds practice rather than isolated technologies or effectiveness claims (Petko et al., 2025; Lee et al., 2025).

Bibliometric and mapping studies have contributed to understanding the growth, distribution, and thematic emphases of research on AI in education, yet they are limited in their capacity to generate conceptual insight into pedagogical practice. By design, bibliometric indicators capture patterns of publication, citation, and keyword co-occurrence, but they do not adequately address questions related to the *nature* of AI use in teaching. Recent methodological discussions therefore argue for the combination of large-scale document analysis with qualitative and interpretive techniques that allow for theory development grounded in empirical material. Such approaches enable researchers to move

beyond descriptive mapping toward the identification of meaningful categories that reflect how educational practices are represented in the literature (de Oliveira, 2024; Crawford, 2025).

At the same time, the use of predefined classificatory frameworks to analyze AI use in education poses methodological risks. Applying external taxonomies or competence models too early in the analytical process may constrain interpretation and lead to circular reasoning, particularly when the same bodies of literature are used both to define analytical categories and to populate them with empirical evidence. To avoid this risk, there is a need for research designs that clearly separate the inductive identification of practice-based categories from subsequent interpretive alignment with conceptual or policy frameworks. Such sequencing allows empirical patterns to emerge from the data before being situated within broader theoretical or normative perspectives (Cohen et al., 2017; Crawford, 2025).

In response to these challenges, the present study adopts a two-stage analytical approach. First, it develops an inductive classification of how artificial intelligence is used by teachers in science education, grounded in the analysis of a large corpus of Scopus-indexed publications. This classification addresses the need for a practice-oriented understanding of AI use that is derived from the literature itself rather than imposing a priori. Second, the study employs the OECD AI Literacy Framework as a second-order analytical lens to interpret how these empirically identified uses align with broader domains of AI-related engagement and competence. By combining grounded category development with deductive framework alignment, the study seeks to contribute both descriptive clarity and interpretive depth, while maintaining a clear distinction between data-driven findings and conceptual interpretation (OECD, 2025; Cohen et al., 2017).

On this basis, the literature review points to a clear research gap: the absence of a systematic, empirically grounded classification of teachers' uses of AI in science education, and a corresponding lack of insight into how such uses relate to established frameworks of AI literacy. Addressing this gap is essential for advancing understanding of current pedagogical practices, informing teacher education and professional development, and supporting policy-relevant discussions on AI integration in education. The following research questions are therefore formulated to guide the analysis (de Oliveira, 2024; Crawford, 2025).

3. Methodology

3.1 Research Design

The present study adopts a qualitative, document-based research design aimed at developing a systematic understanding of how artificial intelligence is used by teachers in science education, as reflected in published research. Rather than examining classroom practice directly, the study treats peer-reviewed publications as empirical material that documents, interprets, and represents educational practice. This approach is grounded in the assumption that research publications constitute a meaningful source for analyzing how pedagogical uses of AI are conceptualized, framed, and reported

within the academic literature, particularly in fields where large-scale empirical access to practice is limited or methodologically challenging (Cohen et al., 2017).

Methodologically, the study combines inductive and deductive analytical logics within a single coherent design. The first stage of the analysis follows an inductive approach, drawing on principles associated with grounded and qualitative content analysis to identify recurring patterns in how AI use by teachers is described across the literature. This stage is deliberately data-driven and avoids the application of predefined classificatory frameworks, allowing categories of AI use to emerge from the corpus itself. Such an approach is appropriate for exploratory research contexts in which existing typologies are either absent or insufficiently sensitive to the diversity of practices represented in the data (Cohen et al., 2017; de Oliveira, 2024).

In a second analytical stage, the study adopts a deductive interpretive perspective by aligning the empirically derived categories with an established AI literacy framework. This sequential design ensures a clear separation between category development and conceptual interpretation, thereby reducing the risk of circular reasoning. The use of a framework at this stage serves not to generate or constrain categories, but to support the interpretation of findings in relation to broader conceptions of AI-related engagement and competence. The combination of inductive category construction and deductive framework alignment allows the study to balance empirical openness with conceptual clarity, while maintaining methodological transparency (OECD, 2025; Crawford, 2025).

Overall, this research design is suited to addressing the study's objectives of mapping and interpreting teachers' uses of AI in science education at scale. By analyzing a large corpus of publications through a structured yet flexible qualitative approach, the study aims to contribute both an empirically grounded classification of AI use and an analytically meaningful connection between documented practices and policy-relevant frameworks. This design positions the study at the intersection of qualitative document analysis, educational technology research, and AI-related educational policy discourse, without privileging any single perspective at the expense of empirical grounding (Petko et al., 2025; Cohen et al., 2017).

3.2 Data Source and Corpus Construction

The data for this study were drawn from Scopus, which was selected as the sole bibliographic database due to its broad coverage of peer-reviewed journals in education, science education, and educational technology, as well as its structured metadata and advanced search functionality. Scopus is widely used in large-scale reviews and document-based studies because it provides consistent indexing standards and facilitates the systematic retrieval of publications across disciplines. The use of a single database was a deliberate methodological choice aimed at ensuring transparency and coherence in corpus construction, while maintaining a manageable and replicable search strategy (de Oliveira, 2024; Crawford, 2025).

A comprehensive search strategy was developed to identify publications relevant to the use of artificial intelligence in science education. The search was conducted by executing a command, which contains combinations of keywords related to artificial intelligence and science education, applied to titles, abstracts and keywords. More specifically, the command was the following:

(TITLE-ABS-KEY ("Science education" OR "Science teaching" OR "Science lesson" OR "Science class" OR "Science learning") AND TITLE-ABS-KEY ("Artificial intelligence" OR "AI"))

Only peer-reviewed journal articles were included, ensuring a baseline level of academic quality and methodological scrutiny. Publications were retained if they explicitly addressed the use of AI in educational contexts related to science teaching or learning, regardless of educational level. No restrictions were imposed on geographical location or methodological approach, allowing the corpus to capture a wide range of perspectives and research traditions (Petko et al., 2025; Li et al., 2025).

The search was re-run prior to the final analysis in order to ensure the currency and completeness of the dataset. This updated retrieval resulted in a final corpus of 795 publications, all of which included abstracts and were therefore retained for analysis. Abstracts were treated as the primary unit of analysis, as they provide concise representations of a study's focus, context, and reported practices, and are commonly used in large-scale qualitative document analyses. The decision to analyze abstracts rather than full texts was guided by the scale of the dataset and the study's aim to identify broad patterns of AI use across the literature, rather than to conduct fine-grained analyses of individual studies (Cohen et al., 2017; de Oliveira, 2024).

The resulting corpus constitutes a structured representation of contemporary research on artificial intelligence in science education as reflected in indexed academic publications. By analyzing abstracts from a large and diverse body of literature, the study seeks to balance breadth and analytical depth, enabling the identification of recurring patterns of AI use while maintaining methodological feasibility. This corpus provides the empirical foundation for the subsequent inductive and deductive analytical procedures described in the following section (Cohen et al., 2017; Crawford, 2025).

3.3 Analytical Procedure

The analytical procedure followed a sequential qualitative approach designed to identify and interpret patterns of artificial intelligence use by teachers in science education. The analysis was conducted on the abstracts of the 795 publications included in the final corpus, which served as concise representations of how AI-related practices were described and framed in the literature. Abstracts in peer-reviewed journals follow structured conventions that summarize study focus and reported practices, making them suitable for large-scale pattern identification. The procedure combined inductive category development with subsequent framework-based interpretation, ensuring a clear separation between data-driven analysis and conceptual alignment (Cohen et al., 2017; de Oliveira, 2024).

In the first phase of the analysis, an inductive coding process was employed to identify recurring ways in which AI use by teachers was described across the corpus. Abstracts were examined iteratively with a

focus on the pedagogical functions attributed to AI within teaching practice, such as instructional support, assessment, planning, or professional activity. Coding was conducted in a bottom-up manner, allowing patterns to emerge from the data without the application of predefined categories or external frameworks. Through repeated comparison and refinement, conceptually distinct yet overlapping categories of AI use were identified. These categories were not treated as mutually exclusive, reflecting the fact that individual publications often described multiple forms of AI use within teaching contexts. During the inductive phase, categories of AI use were developed independently of the OECD domains. The OECD framework was introduced only after category stabilization, at which point a matrix was constructed to examine how the empirically derived categories aligned with broader AI literacy domains. This sequencing ensured that framework alignment did not determine initial category formation. teaching contexts (Cohen et al., 2017; Crawford, 2025).

Following the stabilization of the inductively derived categories, a second interpretive phase was undertaken in which the identified categories were aligned with the OECD AI Literacy Framework. At this stage, the framework was introduced as an analytical lens to support interpretation rather than classification. Each category of AI use was examined in relation to the OECD domains of *Engaging with AI*, *Creating with AI*, *Managing with AI*, and *Designing AI*, enabling the construction of a two-dimensional analytical matrix. This alignment made it possible to explore how empirically identified teaching practices correspond to broader conceptions of AI-related engagement and competence, while preserving the grounded nature of the initial classification (OECD, 2025; Crawford, 2025).

Throughout the analytical process, attention was given to consistency and transparency. Coding decisions were applied systematically across the corpus, and categories were revisited as the dataset expanded from earlier iterations to the final set of 795 publications. The stability of the identified patterns across this expansion was taken as an indicator of analytical robustness. By combining inductive identification of practice-oriented categories with deductive framework-based interpretation, the analytical procedure supports both descriptive clarity and conceptual insight, while avoiding circular reasoning between data and theory (Cohen et al., 2017; de Oliveira, 2024).

3.4 Trustworthiness and Analytical Rigor

Several measures were taken to support the trustworthiness and analytical rigor of the study. First, the analytical procedures were applied consistently across the entire corpus, using the same coding logic and interpretive criteria for all 795 abstracts. The inductive categories were refined iteratively and remained stable as the dataset expanded, suggesting that the identified patterns were not artefacts of a limited sample but reflected recurring ways in which AI use by teachers is described in the literature. Transparency was further supported by the explicit sequencing of inductive category development followed by deductive framework alignment, which reduced the risk of circular reasoning between data and conceptual interpretation (Cohen et al., 2017; de Oliveira, 2024).

In addition, the study relied exclusively on bibliographic data retrieved from Scopus, a curated database of peer-reviewed publications. Clarification was obtained from the Scopus support team confirming that

data extracted from indexed publications may be reused for analytical purposes, including the production of original tables and figures, provided that appropriate credit is given to the source. Accordingly, all quantitative summaries and graphical representations presented in the study were generated by the author on the basis of the retrieved metadata and abstracts, rather than reproduced from existing publications. This approach ensures both ethical use of data and transparency in the presentation of findings (Crawford, 2025).

Coding was conducted by the author using an iterative comparative approach. As the corpus expanded, previously coded abstracts were revisited to ensure consistency in category application. Category definitions were refined through repeated comparison across the dataset, and the stability of coding patterns across the full corpus was taken as an indicator of analytical robustness. This approach aligns with qualitative document analysis procedures in large-scale text corpora (Cohen et al., 2017).

4. Findings

4.1 Inductive Classification of AI Use in Science Teaching

The inductive analysis of the 795 abstracts included in the final corpus resulted in the identification of six categories, describing how artificial intelligence is used by teachers in science education, as represented in the analyzed literature. These categories were derived through a data-driven coding process that focused on the pedagogical functions attributed to AI within teaching practice, rather than on specific tools or technical characteristics. Such an approach is consistent with qualitative document analysis traditions that emphasize the identification of recurring patterns of meaning across large textual corpora (Cohen et al., 2017; de Oliveira, 2024).

The categories identified reflect broad areas of pedagogical activity in which AI is positioned within science teaching. Importantly, the categories are not mutually exclusive. Individual publications frequently described multiple forms of AI use, indicating that AI is often embedded in teaching practice in complex and overlapping ways. This non-exclusive categorization allows for a more faithful representation of how AI use is described in the literature, avoiding artificial separation of practices that may co-occur within the same instructional context (Cohen et al., 2017; Crawford, 2025).

The six categories that emerged from the analysis are: (1) Instructional Delivery and Pedagogy, (2) Assessment and Feedback, (3) Lesson Planning and Curriculum Design, (4) Interactive Agents (Chatbots and Intelligent Tutors), (5) Simulations and Virtual Environments and (6) Teacher Professional Development and Support.

Together, these categories provide a structured overview of the pedagogical roles attributed to AI in science education research, while remaining sufficiently flexible to capture variation across educational levels, contexts, and research traditions (Petko et al., 2025).

Across the corpus, Instructional Delivery and Pedagogy emerged as the dominant category, encompassing more than three-quarters of the analyzed publications. This indicates that AI is most frequently discussed in relation to classroom-facing teaching processes and instructional activity. Assessment and Feedback also constitute a substantial proportion of the corpus, appearing in nearly half of the publications, suggesting sustained interest in AI-supported evaluative and monitoring functions. Lesson Planning and Curriculum Design is present in approximately one-quarter of the corpus, reflecting growing attention to AI-supported preparatory work. The remaining categories—Interactive Agents, Simulations and Virtual Environments, and Teacher Professional Development and Support—appear at lower but still meaningful frequencies, indicating that while these uses are less prominent, they form recurring strands within the broader research landscape. Approximately 11% of publications did not explicitly describe teacher-related AI use within the predefined categories and were therefore classified as unclassified. These publications typically addressed conceptual, policy-oriented, or broader discussions of AI in science education without detailing specific pedagogical applications (de Oliveira, 2024; Crawford, 2025).

Table 1
presents the frequency and percentage distribution of publications across the six categories. As categories are non-exclusive, the total exceeds the number of analyzed publications.

AI use category	Number of publications	Percentage (%)
Instructional Delivery and Pedagogy	619	77.9
Assessment and Feedback	365	45.9
Lesson Planning and Curriculum Design	189	23.8
Interactive Agents (Chatbots and Intelligent Tutors)	123	15.5
Simulations and Virtual Environments	94	11.8
Teacher Professional Development and Support	78	9.8
Unclassified	90	11.3

Table 1. Frequency and percentage distribution of AI use categories in science education (N = 795).

4.1.1 Instructional Delivery and Pedagogy

This category encompasses publications in which artificial intelligence is positioned as a tool that supports or enhances instructional processes during science teaching. AI is described as contributing to classroom activities such as presenting content, guiding inquiry-based learning, scaffolding conceptual understanding, or facilitating interaction between teachers and students. In these studies, AI is integrated directly into teaching practice, often shaping how scientific concepts are introduced, explored, or discussed, rather than functioning solely as a background technology. The prominence of this category reflects the centrality of instructional concerns in discussions of AI use within science education research (Petko et al., 2025; Lee et al., 2025).

4.1.2 Assessment and Feedback

Publications classified under this category describe the use of AI to support assessment-related processes in science education. AI is presented as a means of automating or enhancing formative and summative assessment, providing feedback on student performance, or supporting teachers' evaluative decision-making. These studies frequently frame AI as assisting with the analysis of student responses, monitoring learning progress, or generating feedback aligned with learning objectives. The recurrence of this category indicates sustained interest in AI's potential to support assessment practices and reduce evaluation workload in science teaching contexts (de Oliveira, 2024; Crawford, 2025).

4.1.3 Lesson Planning and Curriculum Design

This category includes publications in which AI is associated with preparatory aspects of teaching, such as lesson planning, curriculum design, or the development of instructional materials for science education. AI is described as supporting teachers in organizing content, aligning learning objectives with activities, or generating instructional resources prior to classroom implementation. Unlike instructional delivery, the focus here is on planning and design processes that occur before teaching takes place. The presence of this category reflects growing attention to AI as a support tool for teachers' preparatory and organizational work (Biagini, 2025; Garzón et al., 2025).

4.1.4 Interactive Agents (Chatbots and Intelligent Tutors)

Publications in this category focus on AI systems that interact directly with learners or teachers through conversational or tutoring interfaces. These include chatbots, intelligent tutoring systems, or other interactive agents designed to respond to queries, guide learning activities, or provide instructional support in science education contexts. In such studies, AI is characterized by its interactive and responsive nature, often functioning as a supplementary instructional presence alongside the teacher. Although less frequent than broader instructional uses, this category represents a distinct form of AI integration centered on dialogue and interaction (Lee et al., 2025; Petko et al., 2025).

4.1.5 Simulations and Virtual Environments

This category comprises publications that describe the use of AI within simulations, virtual laboratories, or immersive environments for science teaching. AI is presented as enabling dynamic modelling of scientific phenomena, adaptive simulation behavior, or interactive virtual experimentation. These studies emphasize experiential and exploratory learning opportunities, allowing students to engage with representations of scientific processes that may be difficult to access in physical classrooms. While comparatively less frequent, this category reflects a specific application of AI aligned with inquiry and experimentation in science education (Jufrida et al., 2025; Li et al., 2025).

4.1.6 Teacher Professional Development and Support

Publications in this category address the use of AI in relation to teachers' professional learning, reflective practice, or instructional support beyond direct classroom teaching. AI is described as assisting with

professional development activities, providing feedback on teaching practices, or supporting teachers in developing competencies related to AI integration. In these studies, AI functions as a resource for teacher growth rather than as a classroom-facing tool. The presence of this category highlights recognition of AI's role not only in teaching and learning processes, but also in supporting teachers' ongoing professional work (Petko et al., 2025; Biagini, 2025).

4.2 Alignment of AI Use Categories with the OECD AI Literacy Framework

Table 2 presents the alignment between the six AI use categories and the OECD AI Literacy domains for the final corpus (N = 795). The patterns below are interpreted as co-occurrences, meaning that a single publication may align with more than one category and more than one domain. Across the matrix, the most prominent pattern is the strong alignment with the OECD domain of Engaging with AI, particularly within the category of Instructional Delivery and Pedagogy, accompanied by substantial secondary alignment with Designing AI. This suggests that a substantial proportion of the literature frames AI use in science teaching not only as interaction with existing systems but also in terms of design-oriented activity, such as developing or configuring AI-supported instructional solutions, adapting AI-enabled environments, or structuring AI-related processes within teaching practice. In this sense, "designing" appears frequently as part of how AI integration is conceptualized in science education research, especially when authors describe the development, adaptation, or structured implementation of AI-supported tools and learning activities (OECD, 2025).

A closely related pattern is the strong presence of Engaging with AI, which is also particularly high in Instructional Delivery and Pedagogy (547) and remains substantial across categories. This confirms that AI use in science education is widely represented as classroom-facing and interactional, involving teachers and students engaging with AI systems during instruction, inquiry activities, or learning tasks. The co-occurrence of high Designing and Engaging values within the same category indicates that the literature often combines descriptions of interactive use with descriptions of the instructional structures or AI-enabled environments that make such interaction possible (OECD, 2025).

The category of Assessment and Feedback shows a similarly multi-dimensional alignment, with strong associations not only with Engaging with AI (265) but also with Designing AI (297) and Creating with AI (204). This indicates that assessment-related publications frequently describe AI use as more than managerial oversight. Instead, they often involve the design or configuration of AI-supported assessment approaches and the generation of assessment-related resources, feedback, or evaluative outputs. While Managing with AI is still present (86), it is less dominant than the combination of engagement, creation, and design, suggesting that assessment-focused uses are frequently framed around how assessment is constructed, supported, or shaped through AI-enabled processes rather than only monitored or administered (OECD, 2025).

Lesson Planning and Curriculum Design also demonstrates substantial alignment with Designing AI (156), alongside meaningful associations with Creating with AI (115) and Engaging with AI (122). This

pattern suggests that planning-related uses frequently include design-oriented activities such as structuring AI-supported resources, aligning AI use with curricular goals, or configuring AI tools to support preparatory work. At the same time, the presence of Creating with AI indicates that planning is often linked with generative functions, such as producing instructional materials or adapting lesson resources, while the Engaging with AI association suggests that planning literature also frequently discusses the anticipated classroom interaction with AI systems as part of the planned instruction (OECD, 2025).

More specialized categories exhibit clear but differentiated alignment patterns. Interactive Agents (Chatbots and Intelligent Tutors) align most strongly with Engaging with AI (107) while also showing strong Designing AI (102), reflecting the combined emphasis on interaction and the construction, adaptation, or instructional integration of conversational systems. Simulations and Virtual Environments show a similar dual emphasis, with Designing AI (132) and Engaging with AI (125) both prominent, consistent with literature that treats virtual environments as both interactive learning spaces and designed AI-enabled systems. Teacher Professional Development and Support also align most strongly with Designing AI (94), indicating that professional-context publications frequently address the design or configuration of AI-supported professional learning resources, alongside engagement and creation-related uses (de Oliveira, 2024).

Taken together, the matrix indicates that AI use in science education is most frequently represented through combined design-oriented and interaction-oriented modes of engagement. Across categories, Designing AI and Engaging with AI are consistently prominent, while Managing with AI appears comparatively less frequent. The alignment with the OECD AI Literacy Framework thus highlights a literature that commonly frames AI integration as involving the development, configuration, or structured implementation of AI-supported educational solutions alongside classroom interaction, rather than focusing primarily on administrative oversight or managerial monitoring (OECD, 2025).

Table 2
Alignment of AI use categories with OECD AI Literacy domains (N = 795)

AI Category	Creating with AI	Designing AI	Engaging with AI	Managing with AI	Unclassified
Instructional Delivery & Pedagogy	325	350	540	217	16
Assessment & Feedback	206	202	321	166	6
Lesson Planning & Curriculum Design	100	125	168	64	4
Interactive Agents	67	75	111	47	5
Simulations	49	47	80	26	3
Teacher Professional Development & Support	50	51	73	35	0
Unclassified	31	33	46	17	28

5. Discussion

5.1 Dominant Patterns of AI Use in Science Teaching

The findings of this study indicate that artificial intelligence is most frequently represented in the literature as a tool supporting core pedagogical functions in science education, particularly instructional delivery and assessment. This pattern suggests that current representations of AI use prioritize immediate teaching needs, such as facilitating classroom interaction, supporting conceptual understanding, and evaluating student learning, over more technically complex or experimental applications. Rather than being framed as a transformative or disruptive technology, AI appears to be largely integrated into existing pedagogical practices, aligning with teachers established instructional responsibilities (Petko et al., 2025; Garzón et al., 2025).

The prominence of assessment- and feedback-related uses further reflects enduring challenges within science education, including the need to monitor learning processes, provide timely feedback, and manage increasing demands for data-informed decision-making. AI is frequently positioned as a means of supporting these evaluative tasks, often with an emphasis on efficiency, automation, or enhanced insight into student performance. This suggests that AI is not only perceived as a teaching aid, but also as a response to structural pressures on teachers' time and workload, particularly in assessment-intensive educational contexts (de Oliveira, 2024; Crawford, 2025).

At the same time, the dominance of these categories highlights a relatively conservative pattern of AI integration. The literature largely frames AI as reinforcing or augmenting existing pedagogical practices rather than reshaping them fundamentally. This finding aligns with broader observations in educational

technology research, where modern technologies are often assimilated into established instructional routines before more transformative uses emerge. In this sense, the findings point to a phase of AI adoption characterized by pedagogical continuity rather than radical change within science education (Petko et al., 2025; Lee et al., 2025).

5.2 Teachers' Roles: Pedagogical Agency over Technical Design

A central insight emerging from the findings is the way teachers are positioned in the literature primarily as classroom-facing users of AI systems and as pedagogical decision-makers who shape how AI is implemented in teaching, rather than as designers or developers of AI systems. Across the analyzed publications, AI is most often described as a tool that teachers select, apply, oversee, or interpret within their existing instructional responsibilities. This positioning reflects a conception of teacher agency that is rooted in pedagogical judgment and professional expertise, rather than in technical authorship or system-level innovation (Petko et al., 2025; OECD, 2025).

The substantial alignment between the identified categories of AI use and the OECD domain of Designing AI suggests that the literature frequently frames AI integration in design-oriented terms. Within this study, this domain is interpreted primarily as involving the pedagogical and organizational shaping of AI-supported teaching, including configuration, adaptation, and structured implementation of AI-enabled tools and learning environments, rather than implying that teachers are developing AI technologies themselves. In this sense, the prominence of Designing AI reflects the extent to which the literature treats AI integration as requiring deliberate instructional and contextual design decisions alongside classroom use (OECD, 2025).

This emphasis on pedagogical agency over technical design may also reflect pragmatic considerations within educational contexts. Teachers operate within institutional, curricular, and temporal constraints that shape the forms of technological engagement that are feasible in practice. As a result, AI is most often appropriated in ways that complement existing teaching roles and responsibilities, rather than requiring teachers to adopt fundamentally new professional identities. In science education in particular, where disciplinary content, inquiry practices, and assessment demands already place substantial cognitive and organizational demands on teachers, AI is positioned as a support for pedagogical work rather than as an object of technical production (Garzón et al., 2025; Lee et al., 2025).

At the same time, the findings do not suggest an absence of creative or innovative engagement with AI but rather indicate that such engagement is typically mediated through pedagogical aims rather than through system design. Teachers' interactions with AI are framed in terms of selecting appropriate tools, interpreting AI-generated outputs, and making informed decisions about their use in teaching and learning contexts. This reinforces the view that teacher agency in AI integration is expressed through pedagogical judgment and contextual adaptation, highlighting the importance of supporting teachers in developing competencies related to critical use and management of AI rather than focusing narrowly on technical design skills (OECD, 2025; Chee et al., 2025).

5.3 AI Use Beyond the Classroom: Planning and Professional Support

The findings also indicate that artificial intelligence is increasingly discussed in relation to teachers' work beyond direct classroom instruction, particularly in the areas of lesson planning, curriculum design, and professional support. Although these uses are less frequent than instructional delivery or assessment, their presence as distinct categories suggest a growing recognition of AI as a resource that supports teachers' preparatory and reflective practices. This pattern reflects an emerging view of AI not only as a tool for facilitating learning activities, but also as a means of assisting teachers in managing the complex organizational and cognitive demands associated with science teaching (Biagini, 2025; Garzón et al., 2025).

In the context of lesson planning and curriculum design, AI is commonly framed as supporting the organization of content, alignment of learning objectives, and generation of instructional materials. These representations position AI as a preparatory aid that operates upstream of classroom interaction, influencing teaching indirectly through planning decisions rather than through real-time instructional engagement. Such uses suggest a shift toward recognizing AI's potential to support the design phase of teaching, while still maintaining teacher control over pedagogical intent and curricular coherence (Petko et al., 2025; Biagini, 2025).

The category of teacher professional development and support further extends this perspective by highlighting AI's role in supporting teachers' ongoing learning and reflective practice. In these publications, AI is described as assisting with activities such as professional feedback, instructional reflection, or the development of competencies related to AI integration itself. While comparatively limited in frequency, these uses signal an awareness of AI as a tool for teacher growth rather than solely for student-facing instruction. This orientation aligns with broader discussions in the literature that emphasize the need to support teachers' professional capacity in navigating emerging technologies, particularly in subject-specific contexts such as science education (Chee et al., 2025; OECD, 2025).

Taken together, these findings suggest that AI use in science education extends beyond the classroom in ways that remain closely tied to teachers' professional responsibilities. Rather than displacing pedagogical expertise, AI is framed as augmenting planning, organization, and professional learning processes. However, the relatively lower frequency of such uses compared to classroom-focused applications indicates that these roles are still developing and may depend on institutional support, access to appropriate tools, and professional development opportunities. As such, AI's role in supporting teachers beyond direct instruction represents an emerging but not yet dominant dimension of AI integration in science education (Garzón et al., 2025; Petko et al., 2025).

5.4 Interpreting the Findings through the OECD AI Literacy Framework

Interpreting the inductively derived categories through the OECD AI Literacy Framework provides a structured perspective on how current representations of AI use in science education correspond to broader modes of AI-related engagement. The updated matrix indicates that AI use aligns most strongly with the domain of Engaging with AI, followed by substantial but secondary alignment with Designing AI, while Managing with AI and Creating with AI appear less prominently. This pattern suggests that AI literacy in science education is primarily framed in terms of active interaction with AI systems, rather than in terms of administrative oversight or advanced technical development.

The dominance of Engaging with AI reflects the classroom-oriented nature of the literature, particularly within Instructional Delivery and Pedagogy and Assessment and Feedback. In these contexts, AI is commonly presented as a tool that teachers and students apply, integrate, and interact with during instructional and evaluative processes. This engagement-oriented framing positions AI as embedded within pedagogical activity, reinforcing the view that AI integration is primarily understood through its practical use in teaching and learning contexts (OECD, 2025; Petko et al., 2025).

While Designing AI also shows substantial alignment across categories, its prominence appears to be linked to the structuring, configuration, or instructional integration of AI-supported systems rather than to the technical development of AI models themselves. In many cases, “design” refers to adapting AI-enabled environments, structuring AI-supported activities, or configuring tools for pedagogical purposes. This indicates that design-oriented discourse in science education research frequently concerns instructional design involving AI, rather than system-level engineering of AI technologies.

Managing with AI appears across categories, particularly in Assessment and Feedback, where monitoring and evaluative oversight are central. However, its comparatively lower frequency suggests that the literature does not primarily frame AI integration as an administrative or governance-oriented activity. Instead, managerial aspects are typically embedded within broader pedagogical processes rather than functioning as the dominant mode of AI engagement (OECD, 2025; de Oliveira, 2024).

Similarly, Creating with AI appears in relation to generative uses, such as producing instructional materials or assessment outputs, but does not surpass engagement-oriented patterns. This indicates that while generative functions are present, they are generally situated within instructional and design contexts rather than representing an independent or dominant mode of AI integration.

Overall, the alignment with the OECD (2025) AI Literacy Framework highlights a literature that conceptualizes AI integration in science education primarily through interactional and pedagogically structured engagement. Design-oriented elements are present but embedded within instructional contexts, and managerial dimensions remain secondary. This pattern reinforces the broader finding that AI use in science education is most frequently framed as an extension of teachers’ pedagogical practice rather than as a shift toward technical authorship or system-level AI development (OECD, 2025; Chee et al., 2025).

5.5 Synthesis of Key Findings and Implications

As drawn from the preceding sections, the findings indicate that artificial intelligence is widely represented in the literature as a pedagogical support resource embedded in multiple aspects of science teaching practice. The inductive categorization suggests that AI is most frequently discussed in relation to instructional delivery and pedagogy, while assessment and feedback also constitute a substantial area of emphasis. At the same time, planning-related uses, simulation-oriented applications, interactive agents, and professional support functions are also present, indicating that the literature increasingly portrays AI integration as spanning both classroom-facing teaching and broader dimensions of teachers' work. Because the categories are non-exclusive, these patterns should be interpreted as overlapping portrayals of practice rather than as isolated or mutually exclusive roles for AI in science education (Petko et al., 2025; Garzón et al., 2025).

Across the analyzed publications, teachers are consistently positioned as active decision-makers who shape AI use through pedagogical judgment and contextual adaptation. However, the updated OECD-based alignment suggests that this agency is not only expressed through interaction and oversight but also through design-oriented engagement. In particular, the prominence of Designing AI alongside Engaging with AI indicates that a substantial portion of the literature frames AI integration in terms of structuring, configuring, and pedagogically shaping AI-supported environments, tools, or instructional sequences, rather than treating AI solely as a ready-made classroom technology. In this sense, the findings suggest that teachers' roles are frequently represented as involving the deliberate design of AI-supported implementation, even when teachers are not positioned as developers of underlying AI technologies or model architectures (OECD, 2025; de Oliveira, 2024).

The synthesis also highlights that Creating with AI remains meaningfully represented across multiple categories, particularly in areas such as lesson planning, curriculum-related work, and assessment-related tasks where generative functions can support preparation, resource adaptation, and feedback production. Meanwhile, Managing with AI appears less prominent than in earlier interpretations, although it remains relevant where monitoring, evaluation, and responsible oversight are central. Taken together, these patterns support a view of AI integration in science education as multi-dimensional: the literature frequently combines interactive use with design-oriented and, in many cases, creation-oriented representations, reflecting the complexity of real teaching contexts and the tendency for AI tools to serve multiple functions within a single instructional setting (OECD, 2025; Chee et al., 2025).

In terms of implications, the findings support the value of conceptualizing AI integration through teachers' practices rather than through tool types alone. The six-category typology provides a practical lens for organizing a diverse research landscape, while the OECD alignment offers an additional interpretive structure for understanding how AI-related engagement is framed in the literature. For teacher education and professional development, the results suggest that support should not focus only on tool adoption and classroom interaction, but also on the design-oriented competencies required to integrate AI meaningfully into science teaching, including configuring tools, structuring AI-supported learning environments, and aligning AI use with disciplinary goals such as inquiry, modelling, and evidence-based reasoning. At the same time, the continuing presence of assessment and planning

applications indicates the need to address responsibility, transparency, and professional judgment in relation to AI outputs, particularly where AI influences evaluation or instructional decisions (OECD, 2025; Crawford, 2025).

6. Conclusions

This study sets out to provide a systematic and empirically grounded account of how artificial intelligence is represented as being used by teachers in science education, drawing on a corpus of 795 Scopus-indexed publications. The findings indicate that AI is most frequently positioned within core pedagogical functions, particularly instructional delivery and assessment-related practices. Across the literature, AI is described as supporting classroom interaction, guiding inquiry processes, scaffolding conceptual understanding, and facilitating formative and summative evaluation. While additional uses—such as lesson planning, simulations, interactive agents, and professional development—are clearly present, they appear less prominently than classroom-facing instructional and assessment applications. Because the categories were developed inductively and applied non-exclusively, these patterns reflect overlapping representations of practice rather than mutually exclusive domains of AI integration.

When interpreted through the OECD (2025) AI Literacy Framework, the identified categories align most strongly with Engaging with AI, followed by substantial but secondary alignment with Designing AI. Creating with AI appears meaningfully across planning and assessment contexts, while Managing with AI, although present, is comparatively less dominant. This distribution suggests that AI integration in science education is primarily framed as interactional and pedagogically embedded, rather than as a predominantly administrative or system-level design endeavor. At the same time, the strength of the Designing dimension indicates that AI use is often conceptualized in terms of structuring, configuring, and pedagogically shaping AI-supported tools and environments. In this sense, the literature portrays teachers not merely as passive users of ready-made technologies, but as professionals who actively interpret and adapt AI systems within instructional contexts (OECD, 2025; Chee et al., 2025).

Beyond descriptive mapping, the study contributes theoretically in three interrelated ways. First, it offers a large-scale, inductively derived typology of AI use in science teaching that is grounded in published research rather than imposed from predefined frameworks. By separating category development from subsequent framework alignment, the study responds to methodological cautions regarding circular reasoning in document-based research (Cohen et al., 2017; Crawford, 2025). Second, by aligning the emergent categories with the OECD AI Literacy Framework, the study bridges practice-oriented analysis with broader conceptual discussions of AI-related competence, extending AI literacy discourse into subject-specific educational research (OECD, 2025; Biagini, 2025). Third, the findings reinforce and refine the notion of teacher agency in AI integration. Consistent with technology integration frameworks such as TPACK, AI use is framed as emerging from the interplay between pedagogical aims, disciplinary knowledge, and technological affordances, rather than from technical capability alone (Mishra & Koehler, 2006; Koehler & Mishra, 2009; Petko et al., 2025).

For scholars, the results suggest several directions for future research. Although instructional and assessment uses dominate the literature, areas such as AI-supported professional development and managerial oversight remain comparatively underexplored. Additionally, while the alignment with Designing and Engaging domains is strong, there is limited evidence of research that critically examines the epistemic implications of AI use for science-specific practices such as modelling, experimentation, and evidence evaluation. More fine-grained qualitative studies could deepen understanding of how AI integration affects disciplinary reasoning and inquiry processes in science classrooms. Furthermore, future research may benefit from moving beyond descriptive representations toward comparative analyses across subject domains or educational systems (Jufrida et al., 2025; Li et al., 2025).

For policy and teacher education, the findings indicate that effective AI integration cannot be reduced to tool adoption or technical training. Because AI use is predominantly framed as pedagogically mediated and design-oriented, professional development initiatives should emphasize teachers' capacity to interpret, configure, and critically evaluate AI-supported systems within disciplinary contexts. AI literacy frameworks, including that of the OECD (2025), gain practical significance when connected to subject-specific teaching practices rather than treated as abstract competence models. Supporting teachers in developing critical engagement, generative use awareness, and responsible oversight appears essential for aligning AI use with educational goals (UNESCO, 2021; U.S. Department of Education, 2023; Chee et al., 2025).

Several limitations of the study must be acknowledged. The corpus was constructed exclusively from Scopus-indexed publications, which may privilege English-language and internationally visible research while underrepresenting locally published or non-indexed studies. The analysis was conducted at the level of abstracts rather than full texts, which may limit the depth with which complex pedagogical practices are captured. In addition, the study analyzes representations of AI use in published research rather than directly observed classroom practices; consequently, the findings reflect how AI use is conceptualized and reported, not necessarily how it is enacted in situ. Finally, because categories were applied non-exclusively, frequency counts represent discursive prominence within the literature rather than empirical prevalence of specific practices. The findings should therefore be interpreted as representations of AI use in the published literature rather than as direct evidence of classroom practice. (Cohen et al., 2017; Crawford, 2025).

Despite these limitations, the study provides a structured and empirically grounded overview of how AI use by teachers in science education is currently represented in academic research. While the primary focus is science education, the broader patterns identified—particularly the predominance of engagement-oriented and design-mediated AI use—may extend to other subject areas where teachers operate within similar pedagogical and institutional constraints. The findings suggest that AI in education is being normalized within existing instructional structures, with teachers positioned as pedagogical integrators rather than technical developers. By clarifying how AI use is currently conceptualized, this study offers a foundation for more theoretically informed, practice-sensitive, and policy-relevant research on AI integration in education (OECD, 2025; Chee et al., 2025).

Declarations

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Conflict of interest: The author declares no conflict of interest.

Data availability: The dataset analyzed during the current study consists of bibliographic records retrieved from the Scopus database through institutional access. The use of metadata for academic and non-commercial research purposes complies with Scopus data usage policies. The dataset is available from the author upon reasonable request.

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