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REVIEW **Open Access**

The potential functions of reading and writing activities within scientific inquiry in primary education

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Abstract
Integrating reading and writing instruction with scientific inquiry can enhance student learning, yet the nature of the connections between each of these learning domains remain underexplored. In this systematic review, we analysed 16 interventions in elementary education in order to develop a categorization of the functions of reading and writing within scientific inquiry. Inductive analysis resulted in three main categories of functionalities: reading and writing as support for understanding, doing, and concluding in scientific inquiry. Specific functions belonging to each category are identified and illustrated with learning activities as described in the interventions. These functions highlight a range of possibilities, informing researchers and practitioners about aligning reading and writing with scientific inquiry. The review also included a deductive analysis of instructional reading and writing support in these interventions. Findings revealed that support was minimally described, primarily consisting of explanations (including direct instructions and examples) and providing graphic organizers (e.g., worksheets with prompts). Support for reading activities focused mainly on general and disciplinary-specific strategies for reading comprehension. Writing support emphasized disciplinary-specific strategies such as writing according to an argumentation structure, preparing scientific explanations, and documenting data. The results of this study advance our understanding of the rationale for integrating reading, writing, and scientific inquiry and can inform future integrated interventions. It also underscores the missed opportunities and gaps in current interventions regarding the interactions between reading, writing and scientific inquiry in elementary education.

Keywords Reading comprehension, Writing skills, Scientific inquiry, Educational interventions

Introduction

Reading and writing are integral components of the process of scientific inquiry (Douglas et al., 2006), and are part of the work scientists engage in when conducting research (Latour & Woolgar, 1986). For example, scientists read the scientific literature to determine the knowledge gap, formulate research questions, and combine experimentation with text-based research to answer their research questions. In elementary school science, these reading and writing activities can be mirrored in the process of scientific inquiry. In primary school, the process of scientific inquiry consists of formulating hypotheses,

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designing experiments, drawing conclusions, and communicating findings, which are all scientific practices that are inextricably linked with reading and writing (Enfield, 2014; Glen & Dotger, 2013). Therefore, being proficient in reading and writing age-appropriate science texts can help students to engage in scientific inquiry. Sociocultural perspectives on language learning endorse the relevance of the integration of language instruction with socially and culturally relevant contexts such as scientific inquiry (Lemke, 1990); these theories emphasize the importance of authentic practices for developing language skills (Pearson et al., 2010; Weinburgh et al., 2014).

An increasing body of research suggests that reading and writing in science education should be viewed as more than a transmission of scientific facts from expert sources (Goldman & Bisanz, 2002). Rather, reading and writing should focus on embodying meaningful authentic literacy practices, connected to meaningful contexts that require the use of scientific information in age-appropriate texts (Purcell-Gates et al., 2007; Sørvik & Mork, 2015). Rather than focusing on the memorization and retelling of facts from expert sources, reading texts can contribute meaningfully to authentic science inquiry practices by offering sources of information (Goldman & Bisanz, 2002). In this perspective of science education, there is a distinctive set of reading and writing skills that may contribute to students' ability to engage in effective scientific inquiry. This distinctive set of reading and writing skills inquiry involve, amongst other things, interpreting age-appropriate scientific texts, communicating scientific ideas precisely, and constructing coherent scientific arguments based on evidence. Focusing instruction on these reading and writing skills enables students not only to enhance their proficiency in reading and writing, but also to bolster their scientific knowledge and skills.

Various interventions have been described in the literature that integrate scientific inquiry with reading and/or writing instruction. These studies have demonstrated that integrating scientific inquiry and reading and/or writing instruction has the potential to improve students' learning outcomes for science knowledge, inquiry and design skills, reading comprehension and writing skills (Rhodes et al., 2024). However, there is a large variety of ways in which reading and writing are integrated with science inquiry. Some interventions, for instance, include reading science texts to increase children's background knowledge at the beginning of the scientific inquiry process (e.g. Cervetti et al., 2012), while other interventions focus on reading science texts to learn about experimental procedures (e.g. Hapgood et al., 2004). Similarly, writing activities may, for example, focus on recording data (e.g. Romance & Vitale, 2001) or on drawing conclusions (e.g., Y.-C. Chen et al., 2016). These examples illustrate that reading and writing activities can have different functions for scientific inquiry learning. Nonetheless, because of the discrepancy between everyday language and the specific academic language that is used in scientific inquiry and science texts, only offering opportunities to engage in reading and writing activities does not suffice to increase students' reading and writing skills in the context of scientific inquiry (Douglas, 2006; C. E. Snow, 2010). Students' skills are not likely to advance without appropriate instruction and support (Wellington & Osborne, 2001). A closer examination of integrated scientific inquiry and reading and/or writing interventions is thus warranted to understand the functions of reading and/or writing activities in this context, as well as the instructional support that teachers can offer to support students during these reading and/or writing activities.

Previous studies and current review

Prior studies have expanded our understanding of science and language integration in elementary school from various perspectives. Primarily, the extant literature describes the relation between reading and/or writing and scientific inquiry by focusing on connections between the learning domains. For instance, various studies have elaborated on the alignment between the core practices of (English) language arts and science education (Clark & Lott, 2017; Council of Chief State School Officers, 2012; Lee et al., 2013). Other studies have explored the relation between reading and/or writing and scientific inquiry by focusing on the similarities between scientific and linguistic learning processes. For example, students engage in similar strategies to process information in both situations, such as setting goals, making predictions, drawing inferences, and reaching conclusions (Casteel & Isom, 1994; Hapgood & Palincsar, 2007). Some reviews have described how reading, writing and science can be integrated by detailing historical developments and current trends in practices and research (Rivard, 1994; Yore et al., 2003). Finally, various reviews have demonstrated the effects of integrated instruction in science and language arts on student learning (Bradbury, 2014; Graham et al., 2020; Rhodes et al., 2024).

However, two areas of research remain underexplored. First, there has been limited research on how reading and writing, as fundamental components of language arts, can relate to the pedagogy of inquiry-based learning. The prior literature did not differentiate between science instruction as "reading or talking about science" and inquiry-based or design-based formats ("conducting science"). The language skills that students need to apply in traditional 'text book' science instruction are inherently different from the language that is needed in inquiry-based science learning. Although it is well-established that reading and writing can contribute to students' scientific knowledge development, the specific roles these learning activities play within the context of inquiry learning remain less explored. The second knowledge gap is that previous studies failed to specify how student learning takes place in each phase of the inquiry process and how scientific learning activities are related to specific reading or writing activities. There is a gap between theory and practice in translating the theoretical alignments of reading, writing, and scientific inquiry to student learning. Moreover, little is known about how teachers support students during these reading and writing activities, considering the challenges associated with reading and writing science text.

These gaps present an opportunity to investigate how reading and writing activities can be integrated in the context of scientific inquiry interventions. The current review study aims to offer new insights by focusing on the functions of reading and writing activities within scientific inquiry interventions in elementary education. Additionally, how teachers support student learning in reading and writing activities is investigated. The findings of this study can contribute to the refinement and development of educational practices that integrate and support reading, writing, and scientific inquiry. This study aims to answer the following research questions:

1. What functions do reading and writing activities have in scientific inquiry interventions in elementary education?
2. What instructional support is designed for teachers to provide to students for reading and writing activities in scientific inquiry interventions in elementary education?

Theoretical framework

The learning process of scientific inquiry

Engaging in scientific inquiry involves the investigation and interpretation of natural phenomena by collecting data through experimentation or observation (Pedaste et al., 2015). A major goal of scientific inquiry education is to acquire inquiry skills by engaging in a process that authentically models the activities that scientists engage in during their daily practice (Roth, 2012). In elementary school, scientific inquiry is often organized as a series of stages or phases that describe the activities that students need to carry out, although not necessarily in a linear way. In a comprehensive analysis Pedaste et al. (2015) presented a framework for the inquiry cycle and its sub-phases: orientation, conceptualization, investigation, conclusion and discussion. In the orientation phase, students' curiosity about a topic is raised and a learning challenge is addressed through a problem statement. In the conceptualization phase, theory-based questions and/or hypotheses are formulated. During the investigation phase, students plan their investigation and collect and analyse data based on an experimental design or exploration. The conclusion phase encompasses students presenting their findings by communicating with others and/or reflecting on the whole learning process or its phases.

Reading and writing in scientific inquiry

Reading and writing are integral to scientific inquiry due to the social nature of scientific practices (Latour & Woolgar, 1986; Norris & Phillips, 2003) and the sociocultural role of language in constructing scientific understanding (Wells, 1999). For scientists, it is common practice to explore a new topic first through written materials that describe prior research. This practice helps scientists to understand the current body of knowledge and the theoretical framework, enabling them to establish relevant research questions regarding what is not yet known. Moreover, descriptions of authentic practices of scientific communities highlight that "conducting science" and creating scientific facts is an inherently social process that should not be reduced to the execution of predefined procedures (Latour & Woolgar, 1986).

Although a comprehensive framework for the functions of reading and writing in scientific inquiry education has yet to be established, the existing literature has presented insights into the integration of reading and writing within the scientific inquiry process. These studies have illuminated various ways of implementing reading and writing in the scientific inquiry process. The following sections describe plausible learning activities in each phase of scientific inquiry, according to the framework developed by Pedaste et al. (2015). Within each phase, the potential reading and writing activities to foster inquiry learning are described, based on the existing literature. The resulting overview will provide a starting point for the development of a categorization of the potential functions of reading and writing in scientific inquiry education in elementary education.

Orientation

In the orientation phase, students may observe or perform an experiment to get acquainted with a natural phenomenon. Reading can play an important role in fostering curiosity and drawing attention to what is to be the object of the inquiry (Wigfield & Guthrie, 2000). Reading in the orientation phase aligns with scientists' engagement in extensive reading to review the existing literature on their topic of investigation (Latour & Woolgar, 1986).

In this phase, writing summaries can reduce memory overload. Writing can help generate and record ideas. Writing also stimulates students to reflect on what they learned from the texts they read.

Conceptualization

In the conceptualization phase, students may write research questions or hypotheses that should be aligned with what can be known from the literature, justified by extensive reading and discussions with more knowledgeable people, such as the teacher. Research questions and hypotheses have specific characteristics, and therefore learning to formulate a research question is an important skill that can be developed in this phase (Martin & Veel, 1998).

Investigation

To make up a plan for their investigation, students can read instructional texts such as manuals to gain an understanding of methodologies, equipment, protocols, safety, laboratory procedures and all kinds of practicalities. Science texts can be read that model the inquiry process (Cervetti et al., 2006; Hapgood et al., 2004). To plan their investigations, students can write a research plan. They may develop their own observation or measurement sheets to collect and record the intended data.

Data collection typically involves writing down observations in a lab notebook or notebook (Butler & Nesbit, 2008), often formulated as abbreviated statements (Lederman, 2007), numerical values, symbols, or labels, which can later be accessed to find patterns and make inferences. Typically, the writing is not very grammatical. Entries often only make sense to insiders.

To contribute to the quality of the data collection, students can read about the phenomenon they are investigating in the same science texts as used in the orientation phase, but now with a narrow focus on specific details. To this end, students can be instructed to use data from text sources to answer their research question. This type of reading is sometimes referred to as second-hand investigation or text-based investigation (Goldman et al., 2019; Palincsar & Magnusson, 2013).

To interpret data, comparing such second-hand data with students' own observations can contribute to a better understanding (Cervetti et al., 2006; Hapgood et al., 2004) and to improvements in the data collection process. In general, the data will be compared to the theory, the research question and/or hypothesis, to judge whether the data are good enough to continue to the next phase. Students learn about the findings from others' investigations of similar phenomena through written texts (Millar, 2004; Norris & Phillips, 2003). In this way, science texts can be important for interpretation, because not everything can be observed and manipulated in the science classroom.

Conclusion

In this phase, students may read about conclusions drawn by others (e.g., "experts"). Inquiry in schools is often a re-enactment of an existing experiment, so the students' results and conclusions can be compared to validated outcomes. Texts may also be used to model how scientists draw conclusions from evidence.

Students must learn to recognize the linguistic characteristics of inferences (e.g., the use of connective words; see Fang, 2006) to understand experts' conclusions in texts, as scientists use inferences to explain their observations (Lederman, 2007). Making inferences helps students to synthesize all the information from individual sentences in order to understand the meaning of texts (Best et al., 2005; Kintsch, 1988).

In the conclusion phase, writing activities can help students to organize their ideas, theories, and observations, to construct explanations and formulate conclusions. Writing can be an important tool for transforming global ideas into knowledge that is more coherent and structured and can thereby prompt students to assess, integrate, and expand their knowledge (Chen et al., 2013; Y.-C. Chen et al., 2016). Students need to link information from texts and other resources with their own findings and prior knowledge by making their own inferences, using logical connective words, to write explanations about the phenomenon (Glen & Dotger, 2013). Integrating this information requires students to engage in critical thinking, as they compare the result with what a reader might need (Chambliss et al., 2003). In an explanation, a writer makes sense of a phenomenon by describing how and why a phenomenon occurs based on scientific facts and reasoning (Berland & Reiser, 2008). Written explanations contain categories such as examples, analogies, models, and references, which need to be sequenced in a logical way to help readers understand and accept the new information. Furthermore, the writer has to keep in mind specific audiences and their prior level of understanding when deciding what information to use and how to present this (Munkebye & Munkebye, 2013; Pearson et al., 2010).

Discussion

The discussion phase may involve reading activities in which students look for additional evidence that confirms or contradicts their conclusions, or sparks new investigations (Otoide, 2017). Students can compare their ideas or findings with the findings of others, often authoritative sources such as scholars or experts. Reading at this stage might extend students' understanding of their (inquiry) findings and how to interpret them or stimulate students to revisit their initial conclusions.

As the final activity of the inquiry process, students can present their investigations and findings by producing a range of text types (e.g., report, journal article, poster, or blog). Each text type requires a specific use of language (Yore, 2004). Effective writing in science to communicate findings/ideas requires students to be aware of the purpose and audience and adjust their writing accordingly. Reading science texts can show students how to use multimodal representations of data such as text, graphs, and tables and how these are used to support a claim (Hapgood et al., 2004).

Learner support for reading and writing in scientific inquiry

In sum, reading and writing are inherent parts of each phase of scientific inquiry. However, reading and writing in scientific inquiry can be challenging for students

Generally, authentic science texts are characterized by abstract, long and condensed constructions (C. E. Snow, 2010), they are full of metaphors, use the passive voice, contain vocabulary that can be polysemous (with multiple meanings), and use nominalizations (i.e., remodelling of a verb into a noun; Arya, 2011; Goldman & Bisanz, 2014; Halliday & Martin, 2003). Although numerous genres have been identified in science texts Tang et al. (2022) distinguished four major scientific genres having specific purposes, that is: information report, experimental account, explanation, and argument. These genres include different text structures such as question/hypothesis, methods and results in an experimental account, and claim-argument-discussion in argumentative texts (Hapgood & Palincsar, 2007). These text structures indicate the relation between different parts of information in the text. Information reports, for instance, primarily aim to present facts, data, and explanations about scientific phenomena, while arguments are designed to persuade readers about a particular viewpoint. Recognizing the nature of these texts allows students to adjust their reading strategies and critical thinking skills appropriately.

Taken into account these challenges, students need appropriate instructional support in reading and writing activities to help them develop the complex reading and writing skills that are required (Wellington & Osborne, 2001). We define instructional support as the guidance that teachers are intended to provide students for reading and writing, rather than spontaneous support that is offered in practice (e.g., planned vs. interactional language scaffolding; see Gibbons, 2002). Instructional support can be categorized based on the type of language skills that are targeted with the support (general or disciplinary language skills) and the type of support (feedback, hints, instructing, explaining, modelling, or questioning).

General language skills are, for example, reading comprehension strategies or general writing skills such as summarizing. Content-based instruction or Content and Language Integrated Learning are well-known theoretical frameworks rooted in theories of second language learning, in which a general approach to integrating language acquisition with other school subjects is adopted (M. A. Snow, 2001; Stoller, 2008). Providing appropriate content, opportunities for language production and interaction, and feedback on the use of language are important components of these models. Although such support may enhance students' language skills in the context of scientific inquiry, it is less likely that it will suffice to enable students to carry out their scientific inquiry tasks more effectively.

Disciplinary language skills such as engaging in argument through evidence or writing to communicate information co-define scientific inquiry. Language that is produced in specific contexts involves correspondingly specific linguistic features and social functions (Halliday, 1994). Disciplinary literacy is a theory of language underlying this approach that pays attention to the specialized knowledge and skills that are needed to communicate and use knowledge within a particular discipline (Moje, 2007). In the inquiry science classroom students may need to write lab reports or instructional manuals, which are inherently different from the type of texts involved in other school subjects. Therefore, disciplinary language skills can enable students to navigate the language demands of scientific inquiry.

To classify the type of support provided to students while completing learning tasks van de Pol et al. (2011) identified the following categories: feedback, hints, instructing, explaining, modelling, and questioning. These categories were referred to as intervention strategies, which are part of the concept of scaffolding. According to van de Pol et al., the process of scaffolding involves the following steps: diagnostic strategies (Step 1), checking the diagnosis (Step 2), intervention strategies, (Step 3), and checking students' learning (Step 4). Thus, van de Pol et al. made the important distinction between diagnostic and intervention strategies in the process of scaffolding. Diagnostic strategies help to determine the learner's current ability level and deficiencies and indicate the type and level of support needed. Intervention strategies are the actual support strategies used to guide students.

Summary

Regarding our research questions, a comprehensive framework for the functions of reading and writing in scientific inquiry is still lacking. The literature has mainly described potential reading and writing activities, but there is no overview that clearly delineates the various functions that these activities can have in the context of scientific inquiry. Therefore, the current review focuses on developing a categorization of those functions that can be used to better understand the connections between reading, writing and scientific inquiry. To this end, we analysed how reading and writing occur in interventions and how these activities are connected to the phases of inquiry. Additionally, we investigated what instructional support is planned to be offered to students to support reading and writing, considering the complex nature of science texts.

Method

Selection of studies

To answer the research questions, a comprehensive review of the literature was conducted. The selection of the studies to be reviewed is summarized in a PRISMA flow chart in Fig. 1. Systematic searches were carried out in the Web of Science, Scopus, and ERIC databases. In each database, two separate searches were carried out to find the relevant literature describing interventions that included reading and writing. The search strings and limitations for each database are listed in Table 1. Additional relevant studies were found through the "snowball method", by analysing the reference lists of relevant articles to yield further results.

The following inclusion criteria were applied:

1. The study describes a student learning intervention that addresses both scientific inquiry and language (L1) learning.
2. Instructional activities involved a hands-on science activity (i.e., experiment).
3. The study involved students from kindergarten through Grade 6 (ages 4–12).
4. The study was undertaken in a school setting.
5. The study involved a general student population rather than solely focusing on student populations with specific characteristics (e.g., second language learners, students with learning disabilities).
6. The study was peer-reviewed and published in English, in the period 2000–2023.

In our analysis, we included all relevant information about the interventions that was provided in the studies, ensuring that all data pertinent to our research question was considered. Studies that did not explicitly report on an intervention were excluded. Several studies were excluded because they provided too-limited descriptions

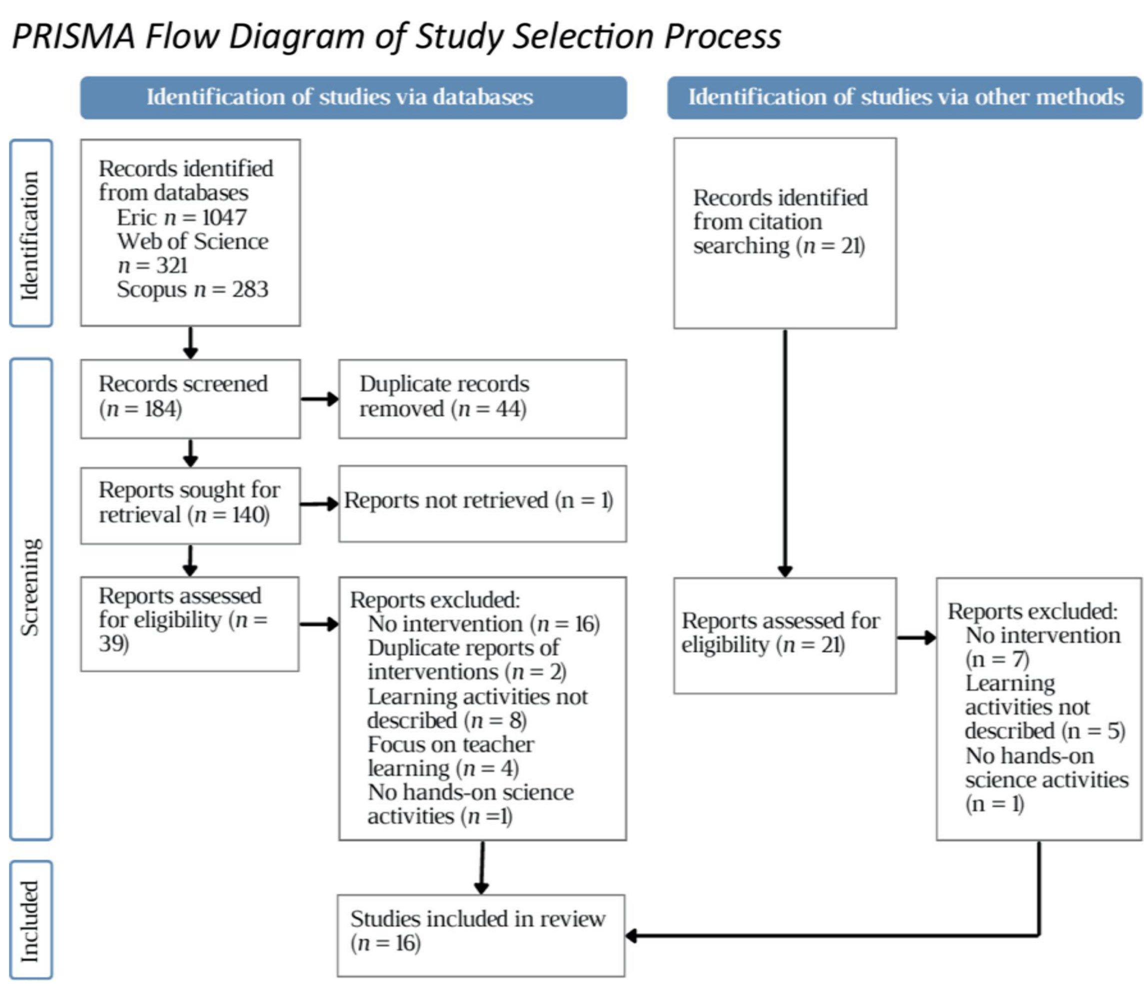

Fig. 1 PRISMA Flow Diagram of Study Selection Process

Table 1 Search Strings, Filters and Limitations Used across Databases for Literature Search

Database	Search string	Filters and limitations used	# records identified	Date of last search
ERIC	(inquiry OR "hands-on science" OR "discovery learning") AND (read* OR text* OR book*) AND ("elementary school" OR "primary school")	Limited by: peer-reviewed, from 2000–now, English	614	8/11/2023
	(inquiry OR "hands-on science" OR "discovery learning") AND (writ*) AND ("elementary school" OR "primary school")	Limited by: peer-reviewed, from 2000–now, English	433	8/11/2023
Scopus	(inquiry OR "hands-on science" OR "discovery learning") AND (read* OR text* OR book*) AND ("elementary school" OR "primary school")	Limited by: from 2000–now, English	195	13/11/2023
	(inquiry OR "hands-on science" OR "discovery learning") AND (writ*) AND ("elementary school" OR "primary school")	Limited by: from 2000–now, English	126	13/11/2023
Web of Science	(inquiry OR "hands-on science" OR "discovery learning") AND (read* OR text* OR book*) AND ("elementary school" OR "primary school")	Limited by: from 2000–now, English	173	8/11/2023
	(inquiry OR "hands-on science" OR "discovery learning") AND (writ*) AND ("elementary school" OR "primary school")	Limited by: from 2000–now, English	110	8/11/2023

of the interventions, which complicated discerning the specific planned learning activities. Some articles were excluded because they only described the enactment of interventions without detailing their original design. Ultimately, 16 studies were included in this review.

Analysis

The included articles were uploaded in ATLAS.ti for individual analysis. To answer the first research question, the first author selected all text fragments in the intervention descriptions in the selected articles that described planned student learning activities involving the reading or writing of texts. Next, each segment was assigned a code that corresponded to one of the inquiry phases proposed by Pedaste et al. (2015), that is, "orientation", "conceptualization", "investigation", "conclusion", "discussion", or "not specified". Subsequently, an inductive analysis was conducted to identify codes that were associated with the function of the reading and writing activities within the context of the scientific inquiry process. The theoretical framework provided descriptions of reading and writing activities that served as a starting point for the analysis. This process was carried out first for the reading activities, and then for writing. Through an iterative procedure of grouping, code categories were progressively refined until thematic saturation was reached. After these individual codes (e.g., build science content knowledge, make claims based on data, or communicate findings) had been defined, the first author identified overarching categories that could capture the essence of the coded data at a higher level. Three primary categories emerged from this process to describe the function of the reading and writing activities in the inquiry process, namely: support for understanding, support for doing, and support for concluding. For instance, reading to acquire science content knowledge (SCK) offers support for understanding, whereas writing to explain scientific phenomena offers support for concluding. After verifying that all individual codes could be assigned to one of the three primary categories, the preliminary coding scheme was finalized, accompanied by detailed descriptions and illustrative examples for each category and individual code. This preliminary version of the coding scheme was then discussed and reviewed with the second author. The main categories and code names and descriptions were adjusted until consensus was reached. Finally, each segment was also assigned a code that corresponded to the genre of the text (i.e., information report, experimental account, explanation, argument or other) that was described in the writing or reading activity. Identifying the type of text helps to show how reading and writing activities contribute to different aspects of scientific inquiry, for example, to factual understanding or to persuasive reasoning. After coding the individual articles, the co-occurrences of codes in the included studies were analysed to identify which reading and writing functions occurred in each phase of the inquiry process.

To answer the second research question, the first author selected the text fragments in the intervention descriptions in the selected articles that described the support that teachers were intended to give to the students in the reading and writing activities. The type of support was coded using the categories identified by van de Pol et al. (2011), namely: feedback, hints, instructing, explaining, modelling, and questioning. In the initial round of coding, another type of support emerged, namely: graphic organizer. This code was therefore added to the coding scheme. The text fragments were also coded according to the type of language the support was aimed at (disciplinary or generic language). The coding scheme, including a description and illustrative examples for each of these codes, was discussed with the second author until consensus was reached. Then, each segment was assigned a definitive code based on this coding scheme. After the individual articles had all been coded, the codes were analysed to identify the number of occurrences of each support variant, and the patterns that emerged from the data.

A sample part of the whole codebook (including the coding rules for both research questions) is presented in Table 2. The complete codebook is available upon request. An independent trained research assistant coded a random sample of 20% of the studies for the calculation of interrater reliability, using the complete and final coding scheme that included all codes related to both research questions. The total agreement was 81.8%.

Results

Distribution of studies

The key features of the included studies are listed in Supplemental Table S1. Most of the studies were conducted in the USA (68.8%), with others undertaken in Taiwan, Canada, and Greece, and were carried out between 2012–2018. In the majority of studies, English was the language of instruction, except for one study conducted in Chinese, and in two cases, the language of instruction was unspecified (these studies were conducted in Taiwan, so the language could have been either Chinese or English). The research scope and types of analysis of the studies is also included in Supplemental Table S1. The studies mainly analysed changes in student learning outcomes as intervention effects. Some studies analysed teacher behaviour (e.g., how teachers used texts in scientific inquiry), how texts support inquiry learning (e.g., interaction between text and hands-on investigations), or students' argumentation practices (e.g., how scientific inquiry nurtures argumentation for meaning making).

The features of the interventions described in the studies are also included in Supplemental Table 1. Figure 2 shows the distribution of the studies regarding the duration of the intervention and the grade level that was included in the study. Out of the 16 studies, 2 included writing instruction, 2 included reading instruction, and 12 included both reading and writing activities. Taking the individual studies as the unit of analysis, Table 3 provides an overview of the number of studies including reading and writing activities per phase of the inquiry cycle, and that writing and reading took place most often in the investigation and discussion phases.

Research Question 1: Functions of Reading and Writing in Scientific Inquiry Interventions

The analysis yielded three primary categories of functions or reading and writing: support for understanding, support for doing, and support for concluding.

Table 4 outlines the studies that included reading and/or writing activities with the various functions that were found in the included studies, for each phase of the inquiry cycle. In the next section, observed functions of reading and writing in each of the phases of the inquiry cycle are described in further detail.

Table 2 Sample Codebook for Instructional Support Types

Code	Description	Example
Explaining	Explanations include the explicit clarification of concepts, strategies, or approach, such as reading comprehension strategies or writing techniques.	"The teacher provides explicit instruction of science vocabulary that occurred in the text" (Wright & Gotwals, 2017).
Instructing	Giving clear and explicit directions or steps for completing a task or understanding a concept.	"Students needed to write down what they had observed and to answer questions about the moon's phases, following worksheet instructions" (Yang & Wang, 2014).
Modelling	Modelling involves explicitly demonstrating effective strategies or techniques to achieve desired outcomes, offering students a clear reference for understanding and applying successful learning approaches.	"Teacher demonstrates how to record information from research resources as a table" (Moreno et al., 2020).
Questioning	Questioning involves posing questions to learners to stimulate thinking, encourage reflection, or assess understanding.	"The teacher supported individual groups to craft high-quality written arguments by asking questions focusing on the argument structure, such as, 'What data do you record?', 'Why do you think those data are important?'" (Y.-C. Chen et al., 2016).
Feedback	Feedback means providing information to learners about their performance or understanding to help them improve.	"There were also activities supporting the students by providing them with checklists or rubrics so that the students could use them in order to evaluate their own arguments (self-assessment) or their peers' arguments (peer-assessment)" (Skoumios, 2023).
Hints	Hints are clues or suggestions provided to learners to help them solve a problem or complete a task independently.	"Figure 3 shows an example of a graphic organizer of an argument that could be used by the students to construct an argument" (Skoumios, 2023).
Graphic organizer	A graphic organizer is a way to show concepts and relationships between concepts from a text using text, illustrations, and/or diagrams. It improves focus, as it helps students organize their information before, during or after reading or writing.	"Teacher guides student use of the concept map constructed in Activity 8 as a blueprint for writing about evaporation and factors that affect evaporation" (Romance & Vitale, 2001).

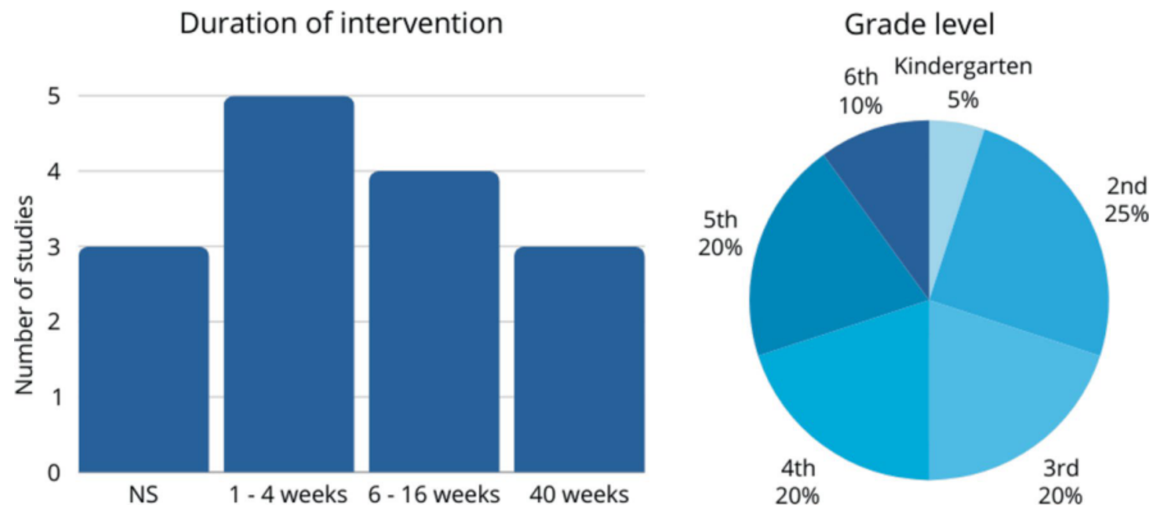

Fig. 2 Distribution of Studies (N = 16). Note: NS = not specified

Table 3 Number of Studies that Included Reading and Writing per Phase of the Inquiry Cycle (N = 16)

Inquiry phase	Reading	writing
Orientation	5	0
Investigation	12	7
Conclusion	0	2
Discussion	3	9
Not specified	5	3

Support for understanding

We assigned studies to the first main category, support for understanding, when reading and writing activities were deployed as a means for students to increase their understanding of the phenomena they are investigating through reading and writing texts about relevant scientific theories and practices. We distinguished three subcategories representing the ways in which reading and writing activities accomplished this goal: provide science content knowledge (SCK), summarize information, and communicate findings.

Provide SCK Within this category, reading activities served to provide students with SCK. Information report was the genre most frequently occurred (four times), with a few instances of an experimental account, one instance of the use of hybrid text (i.e., incorporating multiple text types) and two none specified genres. Four studies included reading activities designed to provide students with SCK In the orientation phase of the inquiry cycle. For instance, in the study by Cervetti et al. (2012), students read a book that "invites students to wonder about whether or not people need light to see". After reading the book, students performed their own experiments with flashlights. In all four studies, the information from the text was meant to raise curiosity for a scientific topic, instead of being an aid for students in formulating or answering a research question. Two studies involved a reading activity that was designed to provide students with SCK in the investigation phase. Romance and Vitale (2001) described a reading activity where students read text passages related to evaporation. Chen (2013) described that students read texts, from which they had to extract main

Table 4 Studies Incorporating Different Reading and Writing Functions Across the Inquiry Cycle

Function		Inquiry phase				
		Orientation	Investigation	Conclusion	Discussion	NS
Support for under-standing	Build SCK (R)	01, 06, 09, 11	10		03, 12	09, 11
	Summarize information (W)		01, 02	09	03, 10	
	Communicate inquiry process and findings (W)				05, 07, 09	
Support for doing	Model inquiry process (R)		06			
	Plan for inquiry (W)		12			
	Acquire data (R)		01, 04, 06, 09, 11, 14			
	Document data (W)		09, 10, 12, 14, 15, 16			07, 13
Support for concluding	Explain scientific phenomena (W)			16		
	Make claims based on evidence (W)				03, 12	
Not specified	Reading	05	02, 05, 14		10	07, 15
	Writing				02, 10, 13	

Note: No studies specified reading/writing activities during conceptualization. R = reading; W = writing. Article numbers are given in Supplemental Table S1 ideas. In both studies, the authors did not describe how reading was related to students investigation, for example, to answer their research question. The reading activity was intended to enhanced students' comprehension and familiarity with the science subject-matter, rather than directly guiding their investigation. Two other studies implemented reading activities to provide students with SCK in the discussion phase. In the study by Y.-C. Y.-C. Chen et al. (2016), students were instructed to compare the arguments they had constructed based on evidence from their hands-on experimentation with ideas from experts in text-based sources. Skoumios (2023) described a reading activity in this phase that required students to analyse texts. Specifically, students had to look for misconceptions, preconceptions, or correct conceptions in a text and locate mistakes. Both activities helped students to solidify their understanding of the science phenomenon they had investigated. Finally, two studies involved reading activities that served to provide students with SCK, but the phase of the inquiry cycle during which students read these texts was not specified. For instance Lai and Chan (2020) merely stated that students were instructed to read science trade books in their inquiry projects.

Summarize information Writing activities can focus on summarizing information, which enhances students' conceptual understanding of a scientific phenomenon. A summary can be categorized as an informational text. One study involved summary writing activities in the investigation phase. Cervetti et al. (2012) incorporated summary writing activities that engaged students in writing about what they had learned after hands-on experimentation and after reading a text about the characteristics of light. The study conducted by Moreno et al. (2020) incorporated a summary writing activity in the conclusion phase. Students wrote a synthesis statement about their inquiry topic. Two studies used writing activities that summarized information in the discussion phase. For example, in the study conducted by Y.-C. Chen et al. (2016) students wrote reflections in their lab notebook on what they had learned in the inquiry-based lessons.

Communicate findings Writing activities can be implemented to communicate findings and conclusions in appropriate ways to others. Three studies included writing activities to communicate findings in the discussion phase. To illustrate, in one of these studies, Isik-Ercan (2020) reported a writing activity that required students to produce a fiction story related to the topic of their inquiry projects. Guthrie (2000) described that students were instructed to write to others in various forms about their understanding of the scientific phenomenon. The text genre was not specified in this study.

Support for doing The second main category, support for doing, involved reading and writing activities that were included to support students' understanding of the methodologies, procedures and steps involved in the inquiry process. In this category, reading and writing supports students' ability to carry out scientific investigations. Here, four sub-categories of reading and writing functions were distinguished: modelling the inquiry process, planning for inquiry, acquiring data, and documenting data.

Modelling the inquiry process The second main category, support for doing, involved reading and writing activities that were included to support students' understanding of the methodologies, procedures and steps involved in the inquiry process. In this category, reading and writing supports students' ability to carry out scientific investigations. Here, four sub-categories of reading and writing functions were distinguished: modelling the inquiry process, planning for inquiry, acquiring data, and documenting data.

Plan for inquiry Writing activities can help students to plan their investigations, by writing a research plan (an experimental account) that describes the methods and materials that will be used. Skoumios (2023) reported that students were instructed to describe their experimental procedures in the investigation phase. The authors did not further specify what the instruction looked like.

Acquire data Students can read texts that are used as a source for data collection (i.e., text-based, or second-hand investigation). Six studies involved reading activities in the investigation phase, with texts providing data that students needed to answer their research question. In four studies, students read information reports, For example, in the study reported by Fitzgerald and Palincsar (2018), students were investigating squirrels and their habitats. In the investigation phase, students read a text that informed them that various structures enable squirrels to climb down trees headfirst. Students had to incorporate this information, together with information gained through experimentation, into a scientific model. In one study students read another genre and in one study, text genre was not specified.

Document data Students can write in a lab notebook (an experimental account) to document their data (i.e., observations or main ideas from texts), which they can use for later reference. Six studies in this review included writing activities in the investigation phase that required students to document their observations in a lab notebook. To illustrate Varelas et al. (2007) incorporated a writing assignment in which students recorded their observations and main ideas from their hands-on and text-based investigations in a lab notebook. In addition, two studies stated that students wrote in their lab notebook throughout the unit, but without linking the activity specifically to phases of the inquiry cycle.

Support for concluding

The third main category, support for concluding, pertained to reading and writing activities that help students to interpret data and draw conclusions. Two sub-categories were defined here: explain scientific phenomena and make claims based on data.

Explain scientific phenomena Writing activities can be implemented to help students to explain the scientific phenomenon they are investigating. Students can be instructed how to use their data to write their explanations. One study incorporated an explanatory writing activity in the conclusion phase. Yang and Wang (2014) described a writing task that required students to explain the regular changes of the moon's phases.

Make claims based on data When students write to make claims based on data, the purpose is to convince the reader by offering arguments including claim, evidence, and reasoning. Two studies included writing activities in the discussion phase that involved making claims based on data. For instance, both Y.-C. Chen et al. (2016) and Skoumios (2023) incorporated argumentative writing activities where students wrote claims based on evidence drawn from their experiments. After constructing their arguments, students engaged in group discussions to negotiate and critique each other's arguments, after which they revised their original arguments.

Function not specified

In several studies, it was not possible to determine the function of the reading and writing activities included in the intervention in the context of scientific inquiry.

For reading, this was the case in seven studies. For instance, Guthrie (2000) described that students were to read a narrative text related to the theme in the orientation phase, but the function of this reading activity was not explicated. A few reading activities that were described in the studies were not explicitly linked with an inquiry phase or a function of reading. For example, Isik-Ercan (2020) stated that "students read a variety of fiction and non-fiction children's literature" (p. 336). To the same end Varelas et al. (2006) described that the teacher read six children literature information books in seven interactive read-aloud sessions. In both examples, it was not possible to derive the function of the reading activity, nor the inquiry phase the activity took place in.

For writing, three studies did not provide enough information to determine the function of the writing activity in the context of scientific inquiry. In these studies, writing activities were limited to writing about the science topic. Three of these studies described a writing activity in the discussion phase. For instance, Romance and Vitale (2001) describe that students were instructed to write about evaporation and factors that affect evaporation. One study did not specify in which phase the writing occurred (Rowell & Ebbers, 2004).

Research Question 2: Instructional Support for Reading and Writing

Table 5 provides an overview of the studies that explicitly described instructional support that was designed to support students reading and writing. Table 6 shows that most of the support concerned explanations (including direct instruction and examples) and graphic organizers.

Out of the 14 studies that included reading activities, five (35.7%) described the instructional support for reading. Four of these studies focused on teaching reading comprehension strategies through explanation and/or modelling. Additionally, one study described the use of reading comprehension questions during reading (Y.-C. Y.-C. Chen et al., 2016). Another study incorporated explicit science vocabulary instruction before reading (Wright & Gotwals, 2017). In one study, the teacher explained the use of science sentence stems (i.e., I observe… I predict…) in texts and modelled how information could be recorded in tables (Moreno et al., 2020). In two of the five studies, the support was aimed at general reading skills, such as general reading comprehension strategies and reading comprehension questions. The other half of the support was aimed at disciplinary reading skills, such as science-specific reading strategies, or science sentence stems.

Five out of the 14 studies (35.7%) that incorporated writing activities specified a type of instructional support for these activities. In two studies, teachers support aimed at the structure of arguments, through various approaches including explanation, graphic organizers, hints (in the form of worksheets with guiding prompts), feedback, and questioning. In another study, the instructional support addressed how to summarize information and write scientific explanations, through explanation, modelling, and graphic organizers. One study described the use of a graphic organizer (i.e., a concept map) to support writing a text (Romance & Vitale, 2001), while another study incorporated a worksheet with hints to assist in writing experimental procedures and recording data (Skoumios, 2023). Finally, in one study explanations were provided on how to record data as observations and on the difference between description and explanation in writing (Yang & Wang, 2014). All of the studies included support that was aimed at disciplinary writing skills. One study included support for both disciplinary (writing

Table 5 Instructional Support to be Provided to Students in Interventions for Reading and Writing

	Study	Support type	Type of language targeted	Content of the support
Reading	Cervetti et al. (2012)	Explanation, modelling	GL	Reading comprehension strategies (predicting, summarizing)
	L. C. Chen (2013)	NS	DL	Reading comprehension strategies
	Guthrie (2000)	Explanation	GL	Reading comprehension strategies (how to integrate across information sources, including texts, illustrations, references, and human experts)
	Moreno et al. (2020)	Explanation	DL	Science sentence stems
		Modelling	DL	How to record information in tables
		Explanation, modelling	DL	Reading comprehension strategies
	Wright and Gotwals (2017)	Explanation	DL	Science vocabulary
Writing	Cervetti et al. (2012)	Explanation, modelling, graphic organizer	GL, DL	Writing strategies (summarizing, writing scientific explanations)
	Y.-C. Chen et al. (2016)	Hints, questioning	DL	Components of an argument
	Romance and Vitale (2001)	Graphic organizer	DL	Concept map for writing
	Skoumios (2023)	Hints	DL	Writing experimental procedures, recording data
		Explanation, graphic organizer, hints, feedback	DL	Components of an argument
	Yang and Wang (2014)	Explanation, instruction	DL	Difference between description and explanation
		Explanation, graphic organizer	DL	How to record observations

Note: GL = General language, DL = Disciplinary language. NS = not specified

Table 6 Number of Studies with Specific Types of Instructional Support for Reading and Writing Activities (N = 16)

	Reading	Writing
Explaining	3	2
Instructing	0	1
Modelling	1	1
Questioning	1	1
Feedback	0	1
Hints	0	2
Graphic organizer	1	3

scientific explanations) and generic (summarizing) writing skills.

Conclusion and discussion

The objective of this study was to investigate the functions reading and writing activities have in scientific inquiry, and what instructional support is designed for teachers to support students reading and writing in scientific inquiry in elementary education. Research has not yet focused on how reading and writing activities can be functionally embedded in the various phases of scientific inquiry. In the following sections, the main findings of this study are summarized and discussed.

Functions of Reading and Writing in Scientific Inquiry

The first research question was: What functions do reading and writing activities have in scientific inquiry interventions? An analysis of the included studies yielded a categorization of functions of reading and writing activities within the context of scientific inquiry; namely, reading and writing can offer support for understanding, doing, and concluding. Within each of these three main categories, specific functions of reading and writing activities were described. Not every study included reading and writing activities in all phases or functions, nor should that be the aim. Scholars and practitioners choose a focus that aligns with their objectives. For instance, studies targeting argumentation skills emphasized such activities in the discussion phase (e.g., argumentative writing or analysing arguments in texts).

When looking at the distribution of reading and writing across the phases of the inquiry cycle, it stands out that most reading and writing activities pertained to the investigation phase and discussion phase. Overall, reading activities were most often embedded to enhance students' science content knowledge or to acquire "second-hand" data, while writing activities were most often embedded to document data in a lab notebook. No reading and writing activities were described in the conceptualization phase. This is in part an artifact based on the definition of this phase by Pedaste et al. (2015), which limits this phase to the formulation of research questions and/or hypotheses. Consequently, reading or writing activities relevant to *developing* these questions or hypotheses were scored under "orientation" in this review. There were only two instances of reading and writing activities in the conclusion phase (Moreno et al., 2020; Yang & Wang, 2014). The limited number of reading and writing activities in the conclusion phase described in the included studies indicates missed opportunities for employing reading and writing in this phase.

In a substantial number of the included studies the specific function of the reading or writing activities within the context of science inquiry, could not be identified. This could indicate that intervention descriptions did not provide enough detail to determine their function. However, another possibility is that the authors insufficiently considered how and why the reading and writing activities were embedded in scientific inquiry education. For instance, some studies failed to specify how students should apply the information they read in texts in their investigations. In other studies, students had to write about a science topic without explicitly linking it to their investigations. These examples illustrate that these reading and/or writing activities were minimally aligned with scientific inquiry learning. reading and writing activities were only superficially connected to scientific inquiry learning and could in fact have been carried out independently from each other. One can wonder if integration would not be more valuable if the activities have a stronger connection to learning in scientific inquiry. This is in line with a growing body of research that promotes the use of authentic literacy activities in school science, by connecting reading and writing activities to meaningful contexts where scientific information from texts (?) must be used by students rather than memorizing factual information (Goldman & Bisanz, 2002; Sørvik & Mork, 2015).

Several recommendations emerged from the findings of the studies, which fell outside the scope of our research questions. While these topics were not directly part of our focus, they are related to the broader context of our findings and offer valuable insights for future research and practice.

First, in the included studies, it was evident that reading and writing contributed to general language functions, such as expressing, communicating, and conceptualizing. For example, in many instances, writing activities were carried out to organize information, which plays a vital role in learning (Rivard, 1994; Wright, 2008). In this regard, Y.-C. Chen et al. (2016) examined the cognitive functions of writing (and speaking) in scientific inquiry. They concluded that the writing events during a scientific inquiry unit mostly focused on cognitive functions such as describing and recording.

Second, some of the included studies stress the importance of making explicit connections between reading and writing, as well as speaking. To this end, Y.-C. Chen et al. (2016) demonstrated that when students engaged in speaking and writing in sequence, the writing activities promoted more higher order cognitive functions (i.e., comparing, integrating, and reflecting on ideas), than when writing occurred in isolation. On a similar note, in their study, Varelas et al. (2006) used the concept of intertextuality to delineate how students and teachers make inferences between information from texts, investigations, and discussions. In this study, we examined the functions of reading and writing separately, but it could be hypothesized that combining reading and writing activities contributes to learning more effectively, and thus also for learning in scientific inquiry.

Third, several studies emphasize that authentic literacy in science not only requires explicit attention to the functions of reading and writing in scientific inquiry, but also requires teachers actively recognizing and seizing opportunities during implementation of the intervention. To this end, Rowell and Ebbers (2004) suggested in their study that although the intervention provided numerous opportunities to engage richly with texts, these opportunities were not always fully recognized by the teachers. The intervention was designed in a way that texts could be used in authentic ways for inquiry learning, for example by examining discrepant information and data from multiple sources. Rather, the teachers often used the texts as opportunities to practice how to structure and organize information, or label or define objects and events. Isik-Ercan (2020) further highlighted the need for teachers to shift their stance towards non-fiction texts as powerful tools for authentic literacy learning, rather than factual accounts that need to be accurately memorized and retold.

A short reflection is warranted on the type of reading and writing activities that are appropriate for scientific inquiry learning in elementary schools. These activities are not meant to replicate the type of reading and writing that professional scientists engage in, so extensive writing is not necessary at this educational level. The focus is on age-appropriate activities, such as constructing simple arguments or summarizing information. One challenge raised in the literature is the potential for cognitive overload, as students may struggle to balance the demands of learning a new writing structure while processing scientific content. This concern is based on the limited attentional capacity model (Skehan & Foster, 2001), which suggests that increasing task complexity may lead students to prioritize one aspect of the task over others. However, this remains largely a theoretical challenge, and many intervention studies demonstrate positive outcomes from integrating reading and writing with scientific inquiry. These studies suggest that, when designed thoughtfully, such integration does not in fact hinder learning and can enhance students' learning outcomes in both language and science (see Rhodes et al., 2024). Therefore, while the cognitive overload concern is valid in theory, it has not been strongly supported in practice, and careful implementation can mitigate these challenges.

Instructional support for reading and writing

The second research question was: What instructional support is designed for teachers to provide to students for reading and writing activities in scientific inquiry interventions? The findings show that a minority of the included studies explicitly described intended instructional support to students in reading and writing activities. This does not necessarily mean that no instructional support was given by teachers, but it was not described in the study as part of the designed intervention, so the nature of the instructional support simply could not be determined in the context of this analysis. It seems surprising that little attention was paid to the instructional support that was designed for teachers to provide to students. Most of the planned support that was described consisted of explanations (including direct instruction and examples) and graphic organizers, which appears to emphasize support that helps students to understand and organize written information through reading and writing in the context of scientific inquiry.

As far as reading support is concerned, it stands out that there was a relatively even divide between general and disciplinary-specific reading support in the included studies. This suggests that there is an understanding of the equal need to enhance general literacy skills while also addressing the unique challenges posed by science texts. Most of the studies that incorporated instructional support for reading targeted general reading comprehension strategies (e.g. Cervetti et al., 2012; Guthrie, 2000). In some studies, the support focused on science vocabulary instruction (Wright & Gotwals, 2017), science sentence stems in texts and interpreting information in tables and figures (Moreno et al., 2020). These types of support are all aimed at helping students to enhance their ability to comprehend the scientific information in the texts. Reading support was rarely aimed at understanding differences between specific features of science text structures. Such discipline-specific reading support could enhance students' reading specifically in the context of scientific inquiry. Given the challenges associated with reading science texts (Arya, 2011; C. E. Snow, 2010), instructional support in this regard can be beneficial for students. In fact, a recent meta-analysis has shown that instruction focused on text structure can improve students' reading comprehension skills (Bogaerds-Hazenberg et al., 2021). On a similar note, Rowell and Ebbers (2004) concluded from their case study that teachers took students' skills at purposeful science reading for granted, and stated that textual resources could be used more effectively by focusing instruction on text structure and graphical information in texts, and by modelling how to look for information in these texts. In this way, the science texts become more than a source of information, serving as examples of how ideas are generated and debated within the scientific community. Therefore, incorporating both general and discipline-specific reading support would seem desirable.

The planned writing support in the selected studies predominantly focused on discipline-specific writing strategies, such as argument structure, scientific explanations, and data recording. Moreover, most instructional support was offered in the form of graphic organizers and worksheets with guiding prompts. This may be attributed to the fact that writing science texts is more closely tied to specific types of texts that depend on the different phases of the inquiry cycle than reading science texts. For instance, writing during the investigation phase often relates to writing a logbook or research plan, while the discussion phase typically involves writing scientific reports or arguments. Global understanding of the science content no longer suffices; knowledge of the text type and its characteristics becomes essential to accomplish the writing task. Thus, many writing tasks are inherently linked with the characteristics and objectives of the phases of the inquiry cycle. This reinforces the need to pay attention to these text features during instruction and to provide discipline-specific instructional support (e.g., how to record information in tables, components of an argument).

Limitations and future research

Our analysis was limited to an exploratory overview of the studies. Claims about the effects of these types of interventions would contribute to our understanding of effective practices in integrating reading and writing with scientific inquiry. However, such analyses have been carried out in other reviews and meta-analyses (e.g. Rhodes et al., 2024) and were outside the scope of the current study. Importantly, the studies included in this review analysed the interventions from various analytical perspectives. Only some of the studies focused on the effect of the intervention on students' learning outcomes. The goal of the current review study was to gain a better understanding of how learning takes place in these interventions, because of the amount of variation in learning activities in the interventions. Our assumption is that by being attentive to the functions of reading and writing for scientific inquiry learning, learning will be significantly enhanced in both areas. This aligns with the view of authentic literacy practices in science education, where the goal is not just to merge subjects but to foster deeper, more meaningful engagement (e.g. Purcell-Gates et al., 2007; Sørvik & Mork, 2015).

Our analysis was challenged by the lack of details in the descriptions of the interventions in the studies. This is not an uncommon finding, as other reviews have reported similar challenges (Rhodes et al., 2024; Rivard, 1994). Most of the studies did not include in their

Methods sections a description of the support intended for teachers to provide during reading and writing activities. This calls for researchers to provide more (detailed) information when reporting on intervention studies, including at least a chronological description of concrete planned learning events, and when and how support was meant to be given to students (by teachers or by means of material resources).

In this review, there was a large (?) variation in how reading and writing activities were conducted, including the use of read-alouds for younger students (Write & Gotwals Otoide, 2017; Varelas et al., 2007, 2006). Formal reading and writing instruction especially in the context of scientific inquiry, does not typically occur in kindergarten. This review focused on intervention studies that included students from kindergarten to Grade 6 and we did not differentiate between these variations in our analysis. From the point of view of scientific inquiry, the same objectives were attained, and (pre)K-1 students were supported in their understanding, doing, and concluding through activities with similar linguistic characteristics. Reading aloud also often occurred with older students too, as did recording data through drawing. In studies with students from upper elementary grades (Grades 4 to 6), students read (?) individually or in groups, and writing activities were increasingly complex (e.g., writing scientific reports or argumentative texts).

This review focused on reading and writing in the context of scientific inquiry. A similar review study could be conducted to examine how oral language activities contribute to scientific inquiry, and how students are supported in these learning activities. Moreover, future studies could further explore the interactions between various language learning activities (e.g., reading and writing, or writing and speaking) in the context of scientific inquiry instruction, expanding on the findings from studies such as Y.-C. Y.-C. Chen et al. (2016) and Varelas et al. (2006).

In conclusion, this literature review outlines a framework delineating the various ways in which reading and writing science texts can support scientific inquiry learning. The framework can aid researchers and practitioners in substantiated decision-making when studying, designing and implementing integrated instruction in reading, writing and scientific inquiry. This review revealed gaps in research and calls for future research to further explore the interactions between reading, writing and scientific inquiry.

Supplementary information

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Supplementary Material 1

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MR contributed to the conceptualization, methodology, and was primarily responsible for the data analysis, writing (original draft preparation), and project administration. MG, HK and AV contributed to the conceptualization, methodology, writing (reviewing and editing), supervision, and funding acquisition. All authors read and approved the final manuscript.

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