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# A scoping review of research on disciplinary use of graphics-text-constructs in didactic learning materials

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# Abstract

Instructional materials are to an ever-greater degree using visual representations to support student learning. The theory of disciplinary literacy shows that distinctive verbal features reflect each subject's approach to cognition and understanding. This emphasizes the need to understand what types of multimodality students encounter in learning materials in and across disciplines. This scoping review creates an overview of what the research literature tells us about how content area literacy is manifested multimodally in didactic learning materials for elementary schools. Didactic learning materials are learning resources made for purposes of teaching and learning. We include 50 methodologically diverse research articles published between 2002-2023. We carry out thematic analysis to understand how disciplinary specificity is manifested multimodally in the articles, whether the focus of the studies is on design, use and/or impact, what methods were used, and whether multimodality is viewed as a resource for supporting learning or as something students need to be taught.

Didaktiske læremidler anvender i stadig større grad visuelle repræsentationer til at understøtte elevernes læring. Teori om disciplinær literacy viser, at karakteristiske verbale træk afspejler hvert fags tilgang til kognition og forståelse. Dette understreger behovet for at forstå, hvilke typer multimodalitet elever møder i læremidler i og på tværs af discipliner. Dette scoping review kortlægger, hvad forskningslitteraturen fortæller os om, hvordan disciplinary literacy kommer til udtryk multimodalt i didaktiske læremidler til grundskolen. Didaktiske læremidler er læringsressourcer lavet med henblik på undervisning og læring. Vi inkluderer 50 metodisk forskellige forskningsartikler publiceret mellem 2002 og 2023. Vi udfører tematisk analyse for at forstå, hvordan fagdisciplinær specificitet kommer til udtryk multimodalt i artiklerne, om fokus i undersøgelserne er design, brug og/eller effekt, hvilke metoder der blev brugt, og om multimodalitet ses som en ressource til at understøtte læring eller som noget eleverne skal lære om.

# A scoping review of research on disciplinary use of graphics-text-constructs in didactic learning materials

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## 1. Background

Learning materials are increasingly multimodal (Kress & van Leeuwen, 2006). In recent decades, the relationship between writing and images in didactic learning materials has shifted, with images playing an increasingly important and prominent role (Bezemer & Kress, 2008; Janko & Knecht, 2014). *Didactic learning material*s are characterized by being designed for specific teaching and learning purposes (Hansen & Gissel, 2017), with at least some degree of didactic intent embedded. This is usually reflected, for example, in explicit learning goals, student tasks, texts of suitable difficulty, and with appropriate scaffolding of the student's acquisition process along with measures for evaluation. A typical example of a didactic learning material is a textbook for a specific subject and grade level, or a course for a specific subject area within a school subject.

### 1.1 Multimodality in learning materials

The use of multiple representations or multimedia in learning materials has the potential to support student learning and comprehension (Mayer, 2014; Mayer & Gallini, 1990) and has also been shown to be a source of student motivation (Suwastini et al., 2021; Male, 2007). However, multimodal constructs such as text-image-constellations can also be challenging for students. For example, occasionally, graphic elements are of little relevance to the topic of the learning material, they can be designed in ways that do not serve the intended didactic purpose, or they can fail to link meaningfully to the verbal text in the learning material.

Research into how learning materials can generally be designed to take advantage of multimodality has already been a major focus of many research studies. In extension, the increasing use of multimodality in learning materials calls for research into (i) how teachers can teach students about multimodality, (ii) the extent to which it is already being taught, and (iii) the impact of this teaching on students' learning. Previous research indicates that we cannot expect teachers to be able to compensate for problematic multimedia design in learning resources. McElvany et al. (2012) showed that teachers of geography, biology, and German L1 were not sufficiently capable of diagnosing the cognitive demands placed on students by the text-image integration in learning materials or of compensate appropriately for it in their teaching.

**1.2 Content-area literacy and multimodality**

These considerations are general in the sense that they are extra-curricular. They do not consider the possibility that each subject has developed its own multimodal content area discourse (i.e. text-image integration may look different in learning materials for teaching English and Geography). In addition to representing different subject content, subjects have developed their own specific ways of talking about and representing the subject content (Shanahan & Shanahan, 2008, 2012; Hillman, 2013). Different subjects use language differently (e.g., Halliday & Martin, 1993; Schleppegrell, 2004). Research has shown that the subject-specific goals in the various subjects are realized through specific disciplinary approaches to academic reading and writing, referred to as "content area literacy" and "disciplinary literacy" (Shanahan & Shanahan, 2008, 2012; Hillman, 2013).

The aim of this literature review is to identify how, and to what extent, research on multimodality in didactic learning materials takes disciplinary literacy into account. Does it show, as we would expect, that each subject's approach to cognition and understanding is reflected in distinct patterns of graphic features in subject-specific learning materials? Does it reveal what types of multimodality students encounter in learning materials within and across disciplines?

Much of the research literature takes a linguistic point of departure. We are interested in how researchers have studied the use of, for example, pictures, graphs, and diagrams in didactic learning materials in elementary schools as co-constituents of the different subject practices (Kress, 2010) and their ways of creating disciplinary meaning (Shanahan & Shanahan, 2008). Therefore, we conducted a literature review guided by this research question:

What can we learn from the research literature about how content area or disciplinary literacy is expressed multimodally in the design of the didactic learning materials used in elementary school, how multimodal constructs are used by teachers and students for disciplinary purposes and what the outcomes of using these constructs are?

The results indicate that only 26 of the included studies specifically address disciplinary aspects of multimodality, while many studies apply general principles of multimedia learning without considering the specific needs of each discipline. Furthermore, the analysis suggests that within the natural sciences, there is a more disciplinary approach to multimodality compared to the humanities.

In the following sections, we will outline our review methodology, our search strategy, and our inclusion and exclusion criteria. Additionally, we will clarify the key concepts of the review and explain how they can be operationalized. We will then present our findings and discuss their implications for future reviews and other research.

## 2. Method

As we expected the body of research literature addressing multimodality in learning materials from a disciplinary literacy perspective to be quite small, we conducted a scoping review (Munn et al., 2018). A scoping review is a type of literature review designed to map the extent of existing research within a specific topic area, identify research gaps, and provide an overall understanding of the subject, while a systematic review focuses on answering a specific research question by gathering and analyzing data from relevant studies using rigorous methods and inclusion criteria.

Our aim was to map the respective foci and findings in the body of literature we might find, and to gain insights into how the use of multimodal elements in didactic learning materials has been studied.

To achieve this, we developed a strategy of block searches in bibliographic databases (the search strings are provided in Appendix 1 for transparency). While we acknowledge that using additional snowballing procedures might have yielded relevant contributions beyond those found in our selected databases, we decided against it.

We selected two databases for our searches: (1) Scopus and (2) Education Resources Information Center (ERIC). We chose Scopus because it is one of the largest databases of abstracts and citations of peer-reviewed literature, covering a wide range of disciplines including science, technology, medicine, and social sciences. It includes high-quality journals ensuring that the literature review is based on credible and authoritative sources. ERIC was chosen for its more specialized educational focus. It includes a vast collection of journal articles, research reports, conference papers, and other education-related materials.

By using both Scopus and ERIC, the literature review benefits from a broad and interdisciplinary perspective (via Scopus) as well as a deep and focused exploration of educational research (via ERIC), which balances the need for a thorough and well-rounded review of the existing literature with the ever present time constraints of the study.

### 2.1 Inclusion and exclusion criteria

Guided by parameters set in our research question, i.e. that we want literature on subject-specific use of multimodality in didactic learning materials for elementary school students, we developed the inclusion- and exclusion criteria for screening listed in Table 1.

**Table 1**
*Inclusion and exclusion criteria*

| Inclusion | Exclusion |
|---|---|
| The study is about teaching and/or learning in elementary school | The study focuses solely on remedial education |
| The study is about didactic learning materials for elementary school | |
| The study is about conventional school subjects such as L1, L2, mathematics etc. | |
| The study is about multimodality (even if it uses other terms) | |
| The study is published in either English, Scandinavian or German | |
| The publication is a peer-reviewed qualitative or quantitative study | |
| The study is published between January 2002 and November 2023 | |

We only included peer reviewed research published between January 2002 and November 2023. We include methodologically diverse research. We exclude studies that focus solely on remedial education

**2.2 Search strings and blocks**

We expressed our research interest with the question:
*What can we learn from the research literature about how "content area or disciplinary literacy is expressed multimodally in the design of the didactic learning materials used in elementary school, how multimodal constructs are used by teachers and students for disciplinary purposes, and the outcomes of using these constructs?"*

We have operationalized the research question as four blocks in our search strategy: (1) content area, (2) multimodality, (3) didactic learning material, and (4) educational sector. In Appendix 1 we present the list of search terms for each block as well as our full search strings.

*2.2.1 Block 1. Content area*

In the first block, we aimed to identify research literature that either explicitly relates to the disciplinary specificity of literacy, i.e., "content area literacy" (Shanahan & Shanahan, 2008) or "disciplinary literacy" (Hillman, 2014) or just focuses on one or more school subjects without using disciplinary literacy as a theoretical basis. One of the themes for analysis is whether the studies on multimodality in didactic learning materials consider the unique characteristics of the disciplines involved. Specifically, whether the subject's requirements, texts, and recognition methods have an impact on the design and strategy for analysis in the study. Thus, studies do not necessarily have to refer to the theory of content area literacy in order to be acknowledged as taking adequate consequences of the fact that each subject is characterized by a disciplinary way of using multimodality in learning materials.

*2.2.2 Block 2. Multimodality*

The concept of 'mode' is central to any multimodal endeavor, so we will touch on it very briefly here. Since the 1990s, several proposals have been made for defining a semiotic mode (Jewitt, 2014), and we acknowledge that multimodal phenomena go by different names in adjacent fields. While our starting point is an interest in multimodality, our aim is not theoretical. We wish to map how the research literature deals with the interaction between verbal elements and images (Kress & van Leeuwen, 2021) in learning materials.

By images we mean visual elements in the broadest possible sense, i.e. any kind of visual design used in didactic learning materials. In the block on multimodality and representations in our search string (see Appendix 1), we included terms such as illustrations, art, image, diagram, graph, etc. along with different theoretical terms for multimodality in an attempt to find studies on the use of non-verbal representations in learning materials to support learning – and to identify these studies even if they do not use theories of multimodality and social semiotics as their theoretical basis.

*2.2.3 Block 3. Didactical learning material*

Identifying studies on *didactic learning materials*, i.e. materials produced for the purpose of teaching and learning (Hansen & Gissel, 2017), requires a broad search strategy. Internationally, there is no common terminology for characterizing this subgroup of learning resources and little terminological rigor. Hence, 'educational', 'didactic', 'instructional', 'learning' or 'teaching' are all relevant search terms in combination with 'aid OR material OR resources OR media' in the international databases. We decided to add 'textbook' and 'reading material' to the phrases.

**Table 2**
*Reasons for exclusion in the full-text assessment and number of excluded records for each reason.*

| Reason for exclusion | Number of excluded records |
|---|---|
| Study not about didactic learning material | 46 |
| Not multimodal focus | 39 |
| Language not Scandinavian, English or German | 17 |
| Not focusing on subject learning | 9 |
| Not research (for example inspirational material for teachers, tools for evaluating learning resources or anecdotal essays) | 9 |
| Wrong setting (elementary school) | 4 |
| Not focused on school subject(s) | 3 |
| Full text not available | 2 |
| **Total** | **129** |

### *2.2.4 Block 4. Sector*

This was the least complicated block, as its sole purpose was to identify studies focusing on elementary school.

### 2.3 Records and manual screening

The search was carried out on November 4, 2023. As expected, our search yielded many hits: 1,107 records in total after removing internal duplicates (Figure 1).

We also expected to exclude many records in the abstract screening process. A total of 928 records were excluded at this stage, leaving 179 articles for full-text assessment performed by two experienced researchers. The reasons for exclusion in the full-text assessment are shown in Table 2. The full-text assessment left us with 50 records for the synthesis.

### 2.4 Synthesis

In the results section, we briefly summarize the text corpus in terms of the school subjects that are the focus of the included studies, the predominant study designs, and the countries of origin. Furthermore, and more elaborately, the analysis and synthesis will shed light on the following questions:

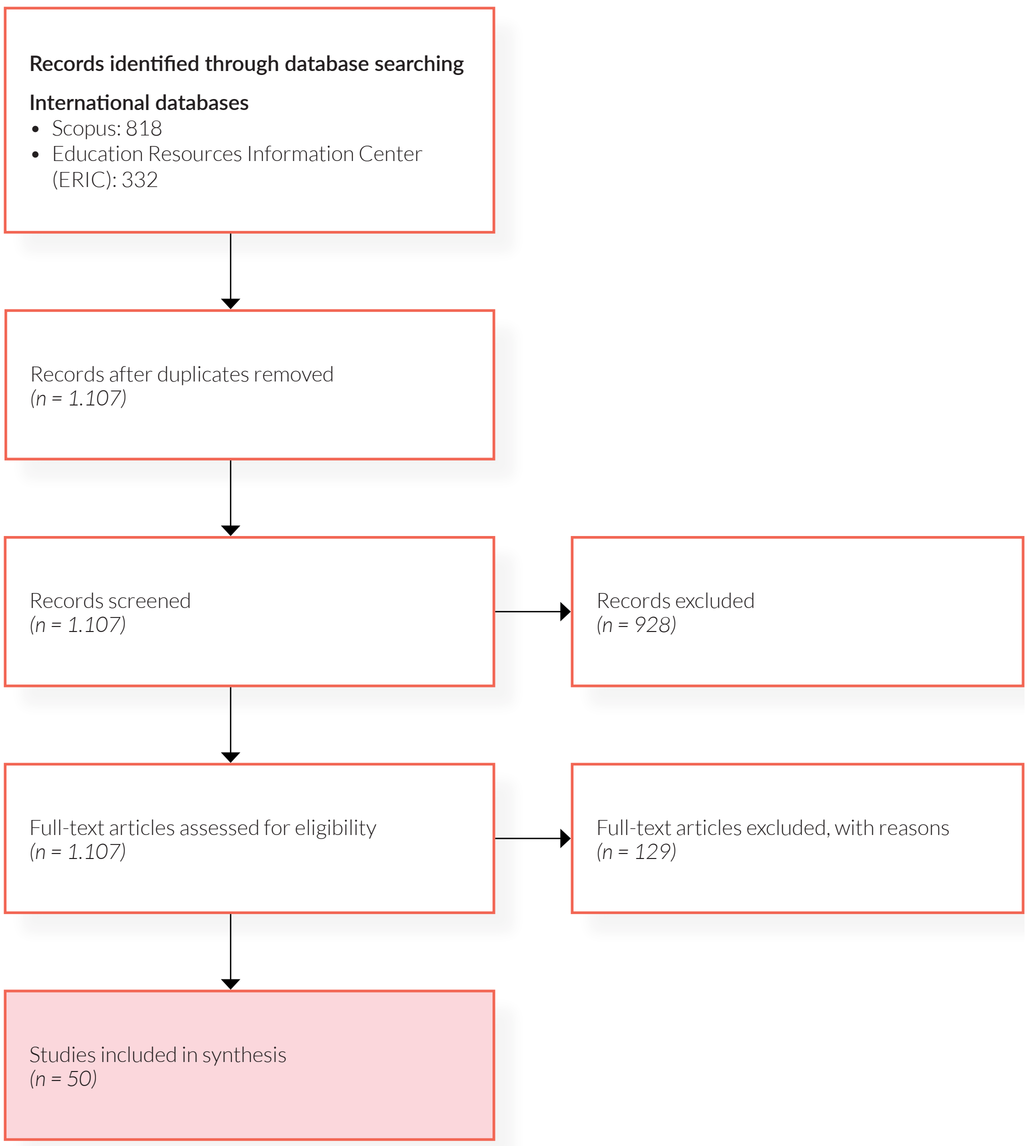
1. *Do the studies establish a link between the use of representations and disciplinary specificity?*

2. *What kinds of representations are studied, and what is the scope of focus on representations?*

3. *What perspectives on studying learning materials are studied? Do they focus on the design of learning materials, examine teacher and/or student use, or determine some kind of outcome related to multimodality in didactic learning materials (Bundsgaard & Hansen, 2011)?*

Of course, studies can combine two or more perspectives, and most studies to some extent include analysis of learning material design. Overall, we distinguish between a) studies that focus on multimodal representations in learning materials as tools for learning/understanding (learning *with* multimodal representations), and b) studies that focus on multimodal representations as objects of teaching/learning (learning *about* multimodality).

**Figure 1.**
*Number of hits from both databases and the total number of hits after removal of internal duplicates, records screened and excluded, number of records assessed in full-text and number of studies included.*



# 3. Results

**3.1 Do the studies establish a link between the use of representations and disciplinary specificity?**
This section examines whether studies on multimodality in learning materials consider the disciplinary specificity of the **subjects** involved. Specifically, it examines whether the subject's requirements, texts, and modes of recognition influence the design and analysis of the studies. 24 of the 50 studies do not condition their research design on the discipline being investigated. Often, the subject and its learning materials serve merely as examples of multimodal texts without influencing the analysis. For example:

— Choi et al. (2023), Fterniati (2009), Hung (2014), Rodríguez-Regueira & Rodríguez-Rodríguez (2022), and Türkeç & Koyuncu (2022) use subjects as random examples.

— Kempe and Grönlund (2019) and Oruç, Uşurlu, and Tokcan (2010) analyze textbooks and multimedia without considering the social science context.

— Schroeder et al. (2011) and Đukičin et al. (2014) focus on general instructional strategies and textbook illustrations without subject-specific considerations.

*3.1.1 Studies Based on Mayer's Principles*
Several studies apply Mayer's (2014) principles of multimedia learning, which are general and interdisciplinary:

— Lenzner, Schnotz, and Müller (2013) used Mayer's theory of integration of multimedia in learning materials as the theoretical basis for investigating the effects of decorative pictures versus instructional pictures. The effects of three conditions were measured: decorative pictures, instructional pictures, or decorative and instructional pictures. The fact that the study is carried out with learning materials for physics does not affect the method or findings.

— Molina et al.'s (2018) choice of using geometry teaching as context for their experiments is only motivated by the claim that geometry can "benefit from the use of multimedia content in which text and illustrations are combined" (Molina et al. 2018, p. 46), which, according to Mayer (2014), would be true for all disciplines.

— Peterson (2016) applies Mayer's theory in the context of science learning materials, with no disciplinary implications in the study design or findings.

— Slough et al. (2010) develop an analytical tool for examining graphical representations in science textbooks that was based on rather general conceptions of form and function, aim (graphics should help students build a mental model of a system), Mayer's spatial-contiguity principle (2014), and general notions of text-graphics integration.

— Schnotz et al. (2014) are interested in students' strategies for integrating text and picture information during learning, rather than highlighting disciplinary-specific aspects of multimodality.

— Ioannou et al. (2009) and King-Sears et al. (2018) apply these principles to social studies and history, respectively, without adapting them to the specific disciplines.

— Cheng et al. (2015) modify science textbooks based on cognitive process principles without subject-specific adaptation.

— Ohle-Peters, McElvany, and Ullrich (2023) examine teachers' competence in using text and instructional pictures without linking to specific school disciplines.

*3.1.2 Disciplinary-Specific Studies*

26 studies explicitly draw consequences from the disciplinary specificity of multimodal learning materials (see Appendix X, column G for full list):

— Walldén (2022) focuses on reading strategies in science texts, highlighting the role of images in conveying disciplinary meanings.

— Gregorius et al. (2010) explain how models of, for example, atoms have limitations and emphasize certain aspects of atoms at the expense of others, which may in turn lead to student misconceptions. These disciplinary considerations lead the authors to experiment with animations as a way of overcoming the limitations of still models.

— Guo, Wright, and McTigue (2018) characterize graphics in science and social studies textbooks, emphasizing disciplinary-specific uses. The categories used to characterize the use of graphics in the two subjects are used to describe disciplinary-specific aims, which are achieved by the specific uses of graphics. Guo, Wright and McTigue (2018) found that the science learning materials had the most diagrams and photographs that functioned representatively, that is, the graphics illustrate parts of the literal meaning of the verbal text or specify the abstract, while social studies used a wider palette of graphics, which were often more challenging in acting interpretatively in relation to the verbal text.

— Huang (2022) and Kus (2022) analyze animations in L2 verbal dialogues and concepts of measures of center in mathematics textbooks, respectively, demonstrating an awareness of the particular challenges these topics can pose for students.

— Norberg (2019) analyses subtraction in mathematics textbooks from a multimodal perspective and with a subject specific interest in how subtraction situations can be created in mathematics learning materials. Vicente et al. (2022) compare illustrations of arithmetic word problems in Spanish and Singaporean textbooks. Žakelj & Klančar (2022) examine the impact of visual representations and visualization in geometry learning.

— Ryoo and Linn (2012), in their comparison of the learning gains from dynamic versus static visualizations, pay close attention to the particular demands and challenges of presenting and learning about energy in photosynthesis. Tang (2023) investigates diagrams in scientific explanations across different science topics, while Singh and Khunyakari (2023) categorize visual representations in biology textbooks. Lee (2010) maps subject-specific purposes of representations in science.

— McKean (2002) maps the distribution and use of artistic representations in social studies textbooks. Šimik (2021) categorizes visual representations in history textbooks. Yu and Liu (2022) explore subject- specific multimodal presentations and digital resources in EFL.

*Conclusion regarding disciplinary specificity in the included studies*

While many studies apply general multimedia principles without considering disciplinary specificity, some research highlights the importance of subject-specific approaches in multimodal learning materials. These studies demonstrate that disciplinary context can significantly influence the design and effectiveness of educational resources. Hence, we recommend that more emphasis be placed on the disciplinary context of the studies in future research on the use of multimodality in didactic learning materials.

### 3.2 Which kinds of representations are studied, and what is the scope of focus on representations?

In this section, we are interested in whether the studies have a narrow focus on representations, for example, a specific type of representation (e.g. diagrams) regarding a specific area within a school subject (e.g. problem solving), or if they study a wider range of representations in the didactic learning materials?

*3.2.1 Studies focusing on the palette of representations in learning materials*

As didactic learning materials are the object of study in this review, many of the included studies examine the palette of modalities present in the learning materials (e.g. Alkhateeb, 2019; Brugar & Roberts, 2017; Cîineanu, 2019; Devetak, Vogrinc, & Glažar, 2010; Guo, Wright & McTigue, 2018; Hung, 2014; Fterniati, 2009; Kempe & Grönlund, 2019; Lee, 2010; Oruç, Uşurlu and Tokcan, 2010; Rodríguez-Regueira & Rodríguez-Rodríguez, 2022; Šimik, 2021; Türkeç & Koyuncu, 2022.

Kempe and Grönlund (2019), for example, broadly analyze the affordances for integration of multimedia and multimodal representations in Swedish collaborative digital textbooks. Lee (2010) mapped all uses of representations in science textbooks, categorizing them according to their instructional purpose  and whether they have an ideational or interpersonal function.

*3.2.2 Broad approach to representations in relation to a narrow disciplinary theme*

The inclusive approach to types of representation can be studied in relation to very specific and narrow disciplinary themes. For example, Kus (2022) narrowly analyses how mathematics textbooks present the concepts of measures of center multimodally, thus including all the representations that are present in the analyzed textbooks. Norberg

(2019) studied subtraction in textbooks, including all the different modes (writing, images, mathematical symbols, speech, and moving images) found in the textbooks, and analyzed their interactions in the presentation of subtraction. Ryoo and Linn (2012) compared the effects of using dynamic and static visualizations to teach 7th- grade students about energy in photosynthesis. Žakelj & Klančar (2022) examine the effects of visual representations and visualization in learning geometry. Singh and Khunyakari (2023) investigated the role of visuals in biology textbook passages on the human digestive system.

#### *3.2.3 Studies focusing on specific representations*

Other studies have a narrower scope via-á-vis which representations are the research interest. For example, Gregorius et al. (2010) study the effects of animations that were produced as part of the study on students' learning gains in chemistry. Similarly, Lee, Chen & Chang (2017) test a mathematics animation teaching system based on iconic representations of mathematics problems. Jee et al. (2022) examined a subset of educational science images that prompt comparison within life science textbooks, which incorporate spatial layouts to facilitate structural alignment, a cognitive process critical for comparison and understanding. Also, Ayabe et al. (2021), Kapıcı and Açıkalın (2015), Lee and Guajardo (2023), Postigo and López-Manjón (2015), Vu and Febrianti (2018), McKean (2002), Yu and Liu (2022) as well as Vungthong, Djonov, and Torr (2017) have a narrow scope of representations in their studies.

An interesting approach to combining width and depth is Tang's (2023) broad content analysis of image functions (narrative, analytical, classificational) in all science textbook diagrams across different text genres (explanation, information, experiment) within the textbooks. This was followed by a narrower multimodal discourse analysis to explore how various image functions combine with linguistic features of the written text in the construction of scientific explanations.

#### *3.2.4 Conclusion regarding scope of representations and disciplinary content*

Both studies with a narrow and broad scope are important. Specific or narrow studies can delve deeply into the affordances and features of the representation in question, but these studies cannot shed light on the palette of representations used for learning purposes within one or more school subjects.

## 3.3 Which perspectives on studying learning materials are in play in the studies?

In this section, we look at the perspectives of the studies. Do they focus on the a) design of learning materials, b) teacher and/or student use, and or c) determine some kind of outcome related to multimodality in didactic learning materials? The first part includes studies that focus on multimodal representations in learning materials as tools for learning/understanding (learning ***with*** multimodality). The second part includes those studies that explore multimodality as an object of teaching/learning (learning ***about*** multimodality).

### *3.3.1 Studies of learning with multimodality in learning materials*

44 of the 50 studies are concerned with learning *with* multimodality through didactic learning materials (see Appendix 2, column H for full list). Several studies (25 in total) report on content analysis of representations in didactic learning materials and use theories such as social semiotics or Mayer (2014) to evaluate the *potential* value of the representations for student learning (Ayabe et al. 2012; Bharath & Bertram, 2018; Cîineanu, 2019; Devetak, Vogrinc & Glažar, 2010; Guo, Wright & McTigue, 2018; Huang, 2022; Jee et al., 2022; Kapıcı & Açıkalın, 2015; Kempe & Grönlund, 2019; King-Sears et al., 2018; Kus, 2022; Lee & Guajardo, 2023; Lee, 2010; Postigo & López-Manjón, 2015; McKean, 2002; Norberg, 2019; Oruç, Uşurlu & Tokcan, 2010; Rodríguez-Regueira & Rodríguez-Rodríguez, 2022; Šimik, 2021; Singh & Khunyakari, 2023; Slough, McTigue & Jennings, 2010; Tang, 2023; Türkeç & Koyuncu, 2022; Vicente et al., 2022; Vungthong, Djonov & Torr, 2017).

Many of these studies are critical of the design of multimodal constructs in the learning materials analyzed. For example, Singh and Khunyakari (2023) found most of the visuals related to the human digestive system to be inadequate and potentially confusing, with weak links between visuals and scaffolding tools, such as activities and exercises. Slough et al. (2010) assessed the appropriateness of graphical representations in science textbooks using Mayer (2014) and found that, in general, graphics were neither spatially nor semantically connected to the verbal text, and that graphics often served only decorative purposes. Kapıcı and Açıkalın (2015) analyzed images representing the particulate nature of matter in science textbooks and found a lack of linkage between images and text, as well as an absence of captions.

### *3.3.2 Design studies that aim at improving student learning gains*

Some studies are experiments that develop new designs aimed at improving students' learning gains from learning *with* multimodality. Lee, Chen, and Chang (2017) designed a mathematics animation teaching system based on iconic representation and explored its learning effectiveness on 4th-grade students.

Zhetpisbayeva, Shelestova, and Kazimova (2017) designed a learning resource for primary school English (L2) and evaluated students' learning gains and motivation. Ryoo and Linn (2012) measured the outcomes of using dynamic and static visualizations, respectively, to teach energy in photosynthesis in science. Fitria et al. (2023) developed a digital comic book on the growth and development of living organisms for science learning in primary school and studied its effect on students´ scientific literacy. Yu and Liu (2022) examined whether text-first or picture-first multimodal input is most efficient for second language (L2) learners' vocabulary meaning. Žakelj and Klančar (2022) designed a model of learning geometry with the use of digital learning resources and measured the impact on students´ geometry skills.

A group of design studies is based on Mayer's (2014) principles of multimedia learning. Gregorius et al. (2010) measured the effects of students learning chemistry through two animations created and tested in the study: one on the states of matter for primary school students (grades 3-5) and another on solution formation for high school students. Cheng et al. (2015) measured the effects of a textbook design according to Mayer's (2014) cognitive process principles and found positive effects on student learning. Molina et al. (2018) used eye-tracking technology to map student behavior and outcomes when using either a learning material with text-image constructs designed according to the principles of spatial contiguity, modality, redundancy, and coherence (Mayer, 2014) or a material that is not designed according to these principles. Ioannou et al. (2009) compared the conditions of a multimedia simulation game in social studies versus a text-only condition and found slightly greater gains in knowledge and interest for the multimedia group.

Peterson (2016) encompasses both textbook design and student outcomes (learning *with* multimodality) by exploring the effects of different schemes for integrating text and images in science textbooks on seventh-grade students' comprehension and their situational interest in the material. Mayer et al.'s (1995) generative theory of textbook design guided Peterson's experimental designs. A within-subjects design was employed with 158 seventh-grade students. The study tested three integration schemes: prose primary, prose subsumed, and fully integrated. The findings suggest that integrating text and images more closely in textbooks may improve students' comprehension and increase their interest in the material, advocating for a rethinking of textbook design practices.

*3.3.3 Findings about how multimodality impacts student behavior*

The four included eye-tracking studies examine student behavior as they interact with the learning resources.

Schnotz et al. (2014) focused on the integration of verbal and pictorial information, examining, through eye-tracking technology, and testing how text and pictures are processed together to construct coherent mental representations. It was found that text and pictures serve different functions in knowledge acquisition, which are associated with different processing strategies. Text is used for coherence-oriented general processing, guiding conceptual analysis, while images are used initially as scaffolds for mental model construction and later for task-driven selective processing.

Hung (2014) used eye-tracking to explore how Taiwanese Grade 6 readers utilize information from various print (main text, headings, captions) and visual elements (decorational, representational, interpretational) to comprehend a science text by tracking their reading behavior and testing students' comprehension. Hung found that illustrations received less attention than print elements, yet readers who fixated more on illustrations had better comprehension. Among print elements, captions received more attention than headings. These findings underline the role of visual elements in supporting text comprehension.

Lenzner, Schnotz and Müller (2013) investigated the effects of decorative pictures versus instructional pictures on learning, focusing on how these pictures influence learners' attention, affective and motivational states, and learning outcomes. The research included three experiments with 7th- and 8th-grade students, using eye-tracking to measure attention, the Multidimensional Mood Inventory for affective states, and multiple-choice items to assess learning outcomes. Decorative pictures were defined as primarily aesthetically appealing, whereas instructional pictures were primarily informative. It was found that decorative pictures attracted less attention and had minimal distracting effects on learners. Furthermore, decorative pictures induced a better mood, alertness, and calmness but did not significantly affect learners' situational interest or perceived difficulty of the material. Decorative pictures neither directly harmed nor benefited learning outcomes but moderated the beneficial effects of instructional pictures (i.e. the multimedia effect, Mayer, 2014), especially for learners with lower prior knowledge.

*3.3.4 Studies about how multimodality impacts classroom practice*

Alkhateeb (2019) used content analysis to examine the mathematical representations and combined this with observational methods to analyze teachers' practices and how teachers used the representations found in the textbooks in their teaching. Alkhateeb (2019) found a significant presence of symbolic and verbal representations in the textbook and teachers' practices. However, other types of representations, such as pictures, figures, models, cutters, and real-life situations, as well as the transitions between these representations, were used to a lower extent both in the textbook and in classroom implementation.

Vu and Febrianti (2018) combined a content analysis of the functions of images in a textbook for English as a foreign language (L2) with interviews with teachers about how they use these images as resources in their teaching. Kress and Van Leeuwen (1996, 2006) were used as a theoretical framework, and Vu and Febrianti categorize the images into three categories: useful, potentially useful, and less useful, based on the roles and functions of the images in the learning activities. The teacher interviews showed that the teachers acknowledged the essential role that images can serve in their teaching, but also that their use of images is limited as a resource for introducing context, stimulating interest, illustration, or simply for decoration. The authors suggest that more attention should be paid to the multimodal nature of the text and its significant contribution to meaningful learning activities.

### 3.4 Studies focusing on learning about multimodality in learning materials

The included studies are seldom preoccupied with learning about multimodality, but those that are mainly focus on teachers as learners.

#### *3.4.1 Teachers as learners*

A few studies are interested in teachers' professional competencies or beliefs regarding multimodal literacy and the relation to student outcomes. Ohle-Peters, McElvany, and Ullrich (2023) examined the influence of teachers' professional competence in teaching with text and instructional pictures, and instructional quality as predictors for developing students' text-picture-integration skills. Data were collected from 136 fourth-grade teachers in Germany, with a subsample of 34 teachers and 646 fourth-grade students participating in a video study on instructional quality. Teachers' competence in teaching with texts and instructional pictures was assessed by questionnaires, and students' text-picture-integration skills were tested in a longitudinal study. A small positive direct effect of teachers' knowledge about students' text-picture-integration skills was identified. Furthermore, aspects of teachers' competence were positively related to instructional quality, with "clarity and structure" significantly predicting students' text-picture-integration skills.

Schroeder et al. (2011) investigated the relationships between teachers' pedagogical beliefs and students' self-reported engagement in learning from texts with instructional pictures. The study aimed to explore how teachers' beliefs about using texts with instructional pictures in teaching were associated with students' engagement, and whether this association was mediated by teachers' instructional behaviors. Schroeder et al. (2011) found that teachers' beliefs that students should be taught clear strategies on how to learn from texts with instructional pictures were positively associated with student engagement. The relationship between teachers' beliefs and students' engagement was mediated by teachers perceived instructional behavior, suggesting that the way teachers incorporate and teach with instructional pictures influences student engagement.

Brugar and Roberts (2017) examined the influence of professional development designed for primary school teachers on their teaching and engagement with graphic devices, such as captioned images, maps, tables, and timelines, found in social studies textbooks. Positive effects of the professional development intervention on students' comprehension of these devices were found.

Danielsson and Selander's (2016) model for working with multimodal texts in education aims to deepen students' understanding of texts, information structures, the textual organization of knowledge, and the cultivation multimodal literacy, particularly in educational contexts, with the intention of emphasizing reciprocal multimodal text analysis in relation to the subject content. The model focuses on the general structure of texts, the operation and combination of semiotic resources, the use of figurative language, and explicit/implicit values in texts.

### *3.4.2 Student learning*

Other studies investigate how multimodality in learning materials supports *student* learning about multimodality. Fterniati's (2009) content analysis study explored the extent to which Greek Language Arts textbooks potentially develop students' multimodal communication skills through the elaboration of multimodal texts. Fterniati (2009) found that the learning designs in the learning materials were insufficient in terms of strengthening students' multimodal literacy.

Choi et al. (2023) examined which teaching strategy was most effective for teaching primary school students integrated reading strategies for illustrated science texts. The authors compared the effects of eye movement modelling examples (EMME), which facilitate learning through observational methods, and prompting, which guides learning through linguistic information. EMME had a significantly greater effect on integrated reading strategies and learning comprehension than prompting. The EMME group demonstrated an integrated reading strategy that involved relating the illustrations and texts, achieving higher average scores on verbal and visual factors than the other groups.

## 4. Conclusion

Through a scoping review, this study examined how disciplinary literacy is multimodally expressed in didactic learning materials for primary and lower secondary education, as well as how teachers and students utilize multimodal constructs for disciplinary purposes. A systematic review of 50 included studies identifies three main categories: (1) studies analyzing the design of multimodal learning materials, (2) studies investigating the use of multimodality in teaching, and (3) studies measuring the outcomes of multimodal integration in disciplinary learning. Among these, 28 of the 50 studies focus solely on analyzing the design of multimodal learning materials.

The findings reveal that only 26 of the included studies explicitly examine disciplinary aspects of multimodality in learning materials. Many studies apply Mayer's (2014) general principles of multimedia learning, which do not account for subject-specific needs and practices. However, the review also indicates a growing interest in exploring how multimodality supports disciplinary understanding, particularly in science and mathematics. Studies that emphasize the significance of subject-specific approaches demonstrate that the disciplinary context significantly influences the design and effectiveness of learning materials. Eye-tracking studies suggest that the integration of text and image plays a central role in students' comprehension and engagement.

The review highlights that the natural sciences exhibit a more explicit disciplinary approach to multimodality, utilizing graphical representations such as diagrams and models with clear disciplinary objectives. In contrast, multimodality in the humanities is often analyzed through general semiotic theories or multimedia learning frameworks, where the subject serves merely as the contextual backdrop for the study. The review also shows that most of the research is conducted in countries outside Europe.

Additionally, the review indicates that teachers often lack knowledge about how multimodality affects students' cognitive (over)load and learning. As a result, teachers may fail to compensate for ineffective multimodal designs in learning materials, potentially hindering student learning.

Finally, the review finds that 44 of the 50 studies focus on learning with multimodality through didactic learning materials, while relatively few studies investigate students' "learning about multimodality," i.e., how students acquire multimodal literacy as an integrated part of their disciplinary competencies.

Overall, the review points to new research opportunities and perspectives. The key conclusion is that greater attention is needed on disciplinary multimodality. This includes investigations into how multimodality varies across subjects (in subject-specific learning materials) and studies on teaching with and about disciplinary multimodality. For instance, how does a focus on subject-specific multimodality support students' development of disciplinary practices and competencies? How do students develop subject-specific multimodal competencies? What implications does this have for their disciplinary learning, and how can teachers effectively teach subject-specific multimodality? Lastly, how can and should learning materials support teachers and students in this endeavor?

The review underscores that subject-specific multimodality remains underexplored in research, highlighting the need for a more nuanced understanding of how disciplinary multimodality can be incorporated and utilized in didactic learning materials for specific subjects. Moreover, the review shows that more research is needed, especially when it comes to humanistic school subjects and research focused on a European school context. School systems and school subjects are highly contextualized, which means, among other things, that research results and findings are not always transferable.

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# Appendix . Search terms and search string

**Table A.1**
*Search terms*

| Block 1: Content area | Block 2: Multimodality | Block 3: Teaching material | Block 4: Sector |
|---|---|---|---|
| content area | art | didactic aid | elementary education |
| content area language | design | didactic material | elementary school |
| content area literacy | diagrams | didactic resources | grade school |
| curriculum | drafting | didactical aid | lower secondary school |
| disciplinary discourse | graphs | didactical material | middle school |
| disciplinary discourse semantics | illustrations | didactical resource | primary education |
| disciplinary education | image | educational aid | primary school |
| disciplinary literacy | image-text | educational material | school |
| discourse groups | lay-out | educational media | |
| discourse semantics | layout | educational resources | |
| genre | multimodal | instructional aid | |
| register | multimedia | instructional material | |
| teaching | multisensory learning | instructional resource | |
| | new literacy | instructional media | |
| | picture | learning aid | |
| | text-image | learning material | |
| | visualization | learning resource | |
| | | reading materials | |
| | | teaching aid | |
| | | teaching material | |
| | | teaching resources | |
| | | textbook | |

**Table A.2**
*Scopus search on November 4th, 2023.*

| Block(s) | Search string | Hits |
|---|---|---|
| 1<br>content area | (content W/0 area) OR (curriculum) OR (disciplinary W/5 (discourse OR literacy)) OR (disciplinary AND (discourse Ww/3 semantics)) OR (discourse W/5 groups) OR (discourse W/5 semantics) OR (genre) OR (new W/3 literacy) OR (register) OR (teaching) | 1.375.391 |
| 2<br>multimodality | (art) OR (color) OR (diagram) OR (drafting) OR (graph) OR (illustration) OR (image) OR (image-text) OR (layout) OR (lay-out) OR (multimodal W/5 semiotics) OR (multimodal AND (social W/0 semiotics)) OR (mult-imodal W/5 text) OR (multimodality) OR (multimedia) OR (picture) OR (text-image) OR (typandraphy) OR (color) | 6.486.084 |
| 3<br>Didactical lear-ning material | (educational W/5 (aid OR material OR resource OR media)) OR (didac-tic W/5 (aid OR material OR resource OR media)) OR (instructional W/5 (aid OR material OR resource OR media)) OR (learning W/5 (aid OR material OR resource OR media)) OR (teaching W/5 (aid OR mate-rial OR resources OR media)) OR (reading W/5 material) OR (text W/5 book) OR (textbook) | 219.343 |
| 4<br>Sector | (elementary W/5 education) OR (elementary W/0 school) OR (gra-de W/3 school) OR (lower W/5 secondary W/5 school) OR (primary W/5 education) OR (primary W/1 school) OR (middle W/1 school) | 175.115 |
| 2 AND 3 | | 32.635 |
| 2 AND 3 AND 4 | | 1.397 |
| **1 AND 2 AND 3 AND 4** | | **818** |

**Table A.3**
*ERIC search on November 4th, 2023.*

| Block(s) | Search string | Hits |
|---|---|---|
| 1<br>content area | (content N0 area) OR (curriculum) OR (disciplinary N5 (discourse OR literacy)) OR (disciplinary AND (discourse N3 semantics)) OR (discou-rse N5 groups) OR (discourse N5 semantics) OR (genre) OR (new N3 literacy) OR (register) OR (teaching) | 640.259 |
| 2<br>multimodality | (art) OR (color) OR (diagram) OR (drafting) OR (graph) OR (illustration) OR (image) OR (image-text) OR (layout) OR (lay-out) OR (multimodal N5 semiotics) OR (multimodal AND (social N0 semiotics)) OR (multi-modal N5 text) OR (multimodality) OR (multimedia) OR (picture) OR (text-image) OR (typography) OR (color) | 199.329 |
| 3<br>Didactical lear-ning material | (educational N5 (aid OR material OR resource OR media)) OR (didactic N5 (aid OR material OR resource OR media)) OR (instructional N5 (aid OR material OR resource OR media)) OR (learning N5 (aid OR material OR resource OR media)) OR (teaching N5 (aid OR material OR resources OR media)) OR (reading N5 material) OR (text N5 book) OR (textbook) | 124.342 |
| Sector | (elementary N5 education) OR (elementary N0 school) OR (grade N3 school) OR (lower N5 secondary N5 school) OR (primary N5 educa-tion) OR (primary N1 school) OR (middle N1 school) | 60.957 |
| 2 AND 3 | | 23.280 |
| 2 AND 3 AND 4 | | 1.037 |
| **1 AND 2 AND 3 AND 4** | | **716 (332 peer reviewed)** |