A Content Analysis of Visuals in Elementary School Textbooks

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ABSTRACT

Although visual complexity is increasing and graphics are essential to support readers' comprehension of disciplinary texts, visual literacy receives scant attention. Research suggests that effectively instructing students to interpret discipline-specific graphics would yield better comprehension. However, before this line of inquiry can be enacted, we must determine the characteristics of graphics in contemporary content textbooks. Therefore, this content analysis evaluated graphics within third- and fifth-grade science and social studies textbooks. We coded 3,844 graphics by type and function and compared findings between disciplines using chi-square and post hoc comparison tests. Overall, graphics were coded into 9 major types (photographs being most frequent) and 54 subtypes, indicating a diversity of graphics. When comparing disciplines, science textbooks contained more diagrams and photographs, and graphics more often functioned representationally. Social studies presented both a wider variety of graphics and more interpretationally challenging graphics. Implications for disciplinary literacy and instruction are discussed.

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As our understanding of disciplinary literacy and text complexity has become more nuanced, have we overlooked any key aspects? We argue: Yes, the visuals. Recently, Common Core State Standards, as well as a growing emphasis on STEM education and disciplinary literacy in elementary

school, have resulted in informational books assuming a progressively prominent role in elementary literacy. Accordingly, students need highly developed skills in genre conventions and structures to navigate these texts (Duke & Billman, 2009; Pappas, 2006). Meanwhile, researchers have also documented the increasing density and complexity of visuals in elementary texts (McTigue & Flowers, 2011; Walpole, 1998) and trade books (Coleman & Dantzler, 2016). However, these lines of research (disciplinary and visual literacy) rarely cross. To advance both, we must consider the discipline-specific uses of visuals, because constructing meaning from modern texts increasingly relies on understanding graphical displays.

Drawing from cognitive psychology and child development, we analyze the visuals within social studies and science textbooks frequently presented to U.S. elementary students. Convergent evidence demonstrates that well-designed visuals can improve learning (e.g., Hannus & Hyönä, 1999; Mayer & Gallini, 1990). However, gaining such benefits from visuals requires knowledge and strategy. Graphic comprehension makes a unique contribution to reading comprehension, beyond the contributions of well-documented factors (e.g., word reading, vocabulary; Roberts, Norman, & Cocco, 2015). Yet visual literacy is not a generic skill because comprehending a specific visual depends on its clarity, format, and content (Palincsar & Duke, 2004). For example, reading a time line in social studies requires the reader to know that lines and arrows represent passage of time, whereas the lines and arrows in a water cycle diagram represent water's movement—a distinctly different construct. To fully access such knowledge, readers must receive discipline-specific instruction in decoding visuals. However, before designing instruction, we must understand what types of visual features students will frequently encounter in content-area school texts—the purpose of this research.

Additionally, when analyzing graphics, we recognize that with the advancement of publishing, both the frequency and the complexity of visuals have increased. Simple frequency counts are insufficient to capture the multilayered displays in modern texts. Therefore, analogous to how the concept of *text complexity* (e.g., Fisher & Frey, 2012) has supplanted more coarse measures of text difficulty (e.g., readability formula), *visual complexity* must also be considered. Although visual complexity has historical use in psychology (e.g., Snodgrass & Vanderwart, 1980), it has typically been applied to a single visual describing both the complexity of the original concept being represented and the conventions of the pictorial representation. However, we conceptualize visual complexity beyond a single representation. Borrowing from text complexity (e.g., Fisher & Frey, 2012), we believe visual complexity represents an interaction of the density and variety of visuals, the intricacy of individual visual representations, the spatial and semantic integration of text and visuals, formatting features (e.g., captions), and reader characteristics.

Following this concept of visual complexity, it is valuable to categorize the types of visuals, their patterns of use, and the integration between visuals and text. Yet, to date, there have been few systematic efforts to quantify visuals in texts. Slough, McTigue, Kim, and Jennings (2010) conducted an analysis of visuals in sixth-grade science textbooks; however, they considered only one grade level, state, and discipline. More comprehensively, Fingeret (2012) analyzed visuals across both science and social studies textbooks and compared findings by discipline, providing a starting point for this work. However, Fingeret's coding method for function yielded little discrim-

ination, with more than 64% of the sample coded as simply *extensional* (i.e., adding information beyond the text base). Recently, Coleman and Dantzler (2016) produced a detailed visual analysis of science trade books; however, their research ended with books published in 2007. Furthermore, because trade books are a distinct genre, findings may not generalize to textbooks. Additionally, visual use has been evolving at a rapid pace, thus dating these studies.

In an age of high-stakes reading and math testing, and when science instructional time is at historically low levels in elementary schools (Blank, 2012) and the allocation for social studies time has fared even worse (Heafner & Fitchett, 2012), one may question whether students are reading informational content texts. Although narrative texts continue to dominate (Jeong, Gaffney, & Choi, 2010), evidence suggests that elementary teachers are integrating informational texts into reading instruction (e.g., Maloch, 2008). Shifting, then, to text use, research indicates that despite increasing informational text and visual content, teachers rarely provide instruction on reading visuals (Coleman, McTigue, & Smolkin, 2011). Inferring from this practice (or lack thereof) suggests that teachers need professional development in visual literacy, which is logical, because they likely did not receive education in visual literacy (Metros, 2008). Furthermore, we have limited knowledge in terms of younger students' developmental progression of visual literacy, especially children's acquisition of visual literacy skills and the strategies they apply when reading multimodal text. However, before this research line can be acquired, we should fully understand the characteristics of visuals that students frequently encounter.

Before embarking on research regarding how to teach visual literacy, we need to fully understand the visual types and complexity readers will encounter. As such, the purpose of this descriptive study was to systematically categorize the visuals in elementary science and social studies textbooks by analyzing their function and form. Our review of previous work, and underlying empirical research, allowed us to merge the most functional aspects of existing coding schemes. These findings will allow researchers and teachers to determine the characteristics of discipline-specific visuals that students most frequently encounter and to develop instructional strategies to support students' comprehension. Additionally, through these findings, we critique the extent to which current texts incorporate theoretical principles of visual design.

Review of Relevant Literature

Although originating in arts and arts education, visual literacy is now the nexus among the fields of arts education, cognitive psychology, literacy, and STEM (science, technology, engineering, and math) education (Baker, 2012). Not surprisingly, researchers do not agree on a single taxonomy, which limits teachers' capacity to instruct on visuals in a systematic manner. Despite variation, researchers have typically classified visuals by form (i.e., type), function, or quality. In this section, we examine the classification schemes informing this work. Next, we discuss the purpose of visuals in textbooks and explore research examining the efficacy of visuals in science and social studies.

Theories Underlying Use of Visuals in Instructional Materials

Our classification scheme is grounded in three interrelated theoretical perspectives: dual coding theory (Sadoski & Paivio, 2013), visual argument hypothesis (Larkin & Simon, 1987), and the conjoint retention hypothesis (Kulhavy, Lee, & Caterino, 1985). In a systematic review, Vekiri (2002) used these theories to explain the benefits of visuals for learning. All three theories are cognitivist and based on the information processing approach to learning, which assumes that working memory limits learning. Thus, these theories posit that adding visuals aids working memory by providing two routes (verbal and nonverbal) for readers to encode and retrieve information (Kulhavy et al., 1985; Sadoski & Paivio, 2013) or by spatially chunking discrete information in groups, thus enhancing memory capacity (Larkin & Simon, 1987). Consequently, the presence of visuals in text can enhance learning (Hannus & Hyönä, 1999; Norman, 2010).

What Are Major Types and Functions of Visuals?

An effective system for categorizing the types of graphics must be specific enough to capture the unique forms of information presented while remaining broad enough to generalize use across situations. Researchers have struggled to strike such a balance. Vekiri (2002) summarized four common types of visuals, each with unique conventions for communication: diagrams, graphs, maps, and (network) charts. In contrast, Fingeret (2012) proposed eight types of visuals with 59 discrete subtypes. Although Fingeret's classification is highly comprehensive, lack of explicit discrimination between certain subtypes renders replication challenging. More recently, connected to Fingeret's work, Roberts and colleagues (2013) classified eight forms: captioned graphics, diagram, flowcharts, graphs, insets, maps, tables, and time lines. This work advanced the field by providing construct definitions and examples for each type.

Beyond form, researchers have also focused on visual function (e.g., Carney & Levin, 2002; Concannon, 1975; Hegarty, Carpenter, & Just, 1996; Levin, Anglin, & Carney, 1987). The five functions established by Levin and colleagues (1987) are most prevalent: (*a*) decorative, (*b*) representational, (*c*) organizational, (*d*) interpretational, and (*e*) transformational. A *decorative* visual serves an ornamental purpose but does not meaningfully support the text (e.g., a cheetah photo on the cover of a biology text). *Representational* visuals show an aspect of the literal meaning (e.g., a photo of Ellis Island with text describing European immigration) and bring concreteness to abstract concepts (Sadoski & Paivio, 2013). *Organizational* visuals categorize information in text (e.g., a table summarizing experimental data). This organizational function is indispensable within informational textbooks because students recall organized information better than discrete facts (Armbruster, Anderson, & Meyer, 1991). *Interpretational* visuals contain elements of both representational and organizational functions but exceed them by presenting information in a manner that assists a reader's comprehension (e.g., an 1860 U.S. map with arrows detailing the troop movement). *Transformational* visuals primarily derive from mnemonics and attempt to recode information into a memorable form (e.g., an atom depicted in a shape of a pen to provide a mnemonic device for *p*roton, *e*lectron, and *n*eutron). More recently, researchers (e.g., Bishop & Hickman, 1992; Fang, 1996; Nikolajeva & Scott, 2000)

added *extensional* visuals, which provide related information not explicitly included in the text (e.g., U.S. rail expansion book with diagrams of locomotives not actually discussed in the text).

How Do Visuals Affect Learning?

Despite sharing theoretical ground, existing research has differing conclusions regarding the efficacy of visuals in textbooks. Primarily quantitative, many afore-mentioned studies focus on students' reading outcomes after studying a visual, such as how a diagram facilitated comprehension. A recent meta-analytic study (Guo, Zhang, McTigue, & Wright, 2017) revealed that the inclusion of visuals has an overall medium positive effect on students' reading comprehension, with an overall effect size of .49.

Yet the type of readers who benefit from visuals is less clear. Earlier work suggested that visuals differentially support low-achieving readers' comprehension (Hayes & Reinking, 1991; Holmes, 1987), which led researchers to infer that the benefit of visuals derived from having information independent of decoding. For instance, Holmes (1987) revealed that although more skilled readers scored higher when processing text (alone), students in both groups performed better with an illustrated text. Other researchers challenged the conclusion that visuals benefited less skilled readers, demonstrating that visuals may be differentially beneficial for skilled readers (Han-nus & Hyönä, 1999; Harber, 1983; Reid & Beveridge, 1986). Eye-movement studies have revealed a potential explanation: Jian (2016) found that children's capacity to integrate information in visuals is limited, possibly because of the cognitive cost of switching between two sources. However, skilled readers are strategic processors who focus on pertinent segments of visuals (Hannus & Hyönä, 1999; Jian & Ko, 2017). Such findings suggest that skilled readers develop more sophisticated strategies for managing multiple sources (Jian & Ko, 2017).

Discipline-Specific Use of Visuals

Research has documented that there are significant differences in the vocabulary, syntax, and text structure across different disciplines (Shanahan & Shanahan, 2012). Specifically, when compared with social studies texts, texts in science contain "many technical vocabularies and dense sentences that require readers to draw on multiple concepts simultaneously" (Fang & Schleppegrell, 2010, p. 588). These unique pat-terns of language require students to rely on discipline-specific approaches to pro-cessing text (Fisher & Frey, 2012), and that requirement has numerous implications for classroom instruction and teacher preparation.

Although the differences in graphics across disciplines have been less explored, disciplinary literacy findings lead us to infer that the types and functions of graphics would also differ markedly across disciplines. For example, Shanahan and Shanahan (2008) demonstrated the manner in which professional scientists attend to graphics while reading (i.e., the process) but provided no analysis of how historians or mathema-ticians approached visuals in their reading. Additionally, except for Fingeret (2012), re-searchers have not compared findings across disciplines. Fingeret quantified specific differences, namely, that the social studies textbooks contained a higher proportion

of maps, whereas science textbooks had more diagrams. However, this study provides few conclusions regarding other types of graphics (e.g., picture, flow chart), visual density, or function differences, thus calling for further investigations.

The Challenges of Reading Visuals in Textbooks

Textbooks (and their visuals) in the United States have been critiqued as an artifact reflecting compromises from political, economic, and cultural interests rather than our most current pedagogical knowledge (e.g., Apple & Christian-Smith, 1991). Given such complex influences, visuals are not selected through rigorous pilot testing, and the resulting texts put the interpretational burden on students (Roberts & Brugar, 2014, 2017; Stylianidou, 2002). For instance, Roberts and Brugar (2014) found that more than 40% of third-grade students misunderstood the purpose of time lines in social studies texts. In science textbooks, Stylianidou (2002) found that students could not easily identify which graphical elements contained the most meaning. Moreover, many students did not perceive the intended message, particularly because they had problems integrating information from the text and the graphics (Stylianidou, 2002). These results call for systematic instructions for the "effective use of graphics, which is [a] multifaceted task—students should be able to read graphics, locate specific information within graphics, create graphics to organize information, [and] communicate to others through the use of graphics" (Coleman et al., 2011, p. 617). Without well-honed visual literacy skills, students are unlikely to employ graphics to their fullest potential.

Despite the need for specific instruction in reading visuals, U.S. teachers' instructions in this area are limited in both frequency and depth (Brugar & Roberts, 2017; Coleman et al., 2011). When asked about their practices for assisting children in interpreting graphics, Coleman et al. (2011) found the most frequent instructional activity was pointing at graphics. However, according to Peeck (1993), although such instructional practice may help students attend to graphics, it does little to support visual comprehension skills. In contrast, instructional practices that would better scaffold students to develop visual processing skills (e.g., creating or comparing visuals) were rarely reported. For instance, a large proportion of teachers reported they *never* or *rarely* taught students to draw and label graphics (73% and 49%, respectively), nor did they have students explain a graphic (35%). Teachers' lack of preparation or attention to visual literacy is not specific to the United States; it is also documented in South Africa (Moodley, 2013) and Norway (Erstad, 2012). In contrast, in Australia, visual literacy has been part of the national curriculum for a decade and includes critical aspects of visual literacy (Callow, 2008), providing a model for other nations.

Purpose and Research Questions

The purpose of the current study is to evaluate the visuals in third- and fifth-grade science and social studies textbooks to better inform researchers and educators who are seeking to support students' visual literacy. As recommended by Pearson and Hiebert (2014), we developed and used a qualitative system for coding the visuals and describing how they may add to text complexity. Our research is guided by the fol-

lowing questions: (1) What types of visuals are present in third- and fifth-grade science and social studies textbooks, and what are the semantic functions of those visuals? (2) Do the types and semantic functions of visuals differ in science and social studies textbooks? If so, how do they differ?

Method

Definition of Visuals

In this study, we analyzed visuals in informational texts, "whose primary purpose is to convey information about the natural, social, or physical world, and that has particular linguistic features to accomplish the goal" (Duke & Billman, 2009, p. 110). Consistent with previous research (Norman, 2012), we defined *visuals* as graphical displays, which are not limited to diagrams, maps, graphs, and tables. A visual may contain some text, such as labels on a regional map, or a caption; however, the main source of information comes from visual, rather than textual, presentation. Not all visuals in textbooks meet this definition (Fingeret, 2012). For instance, Slough and colleagues (2010) found that approximately 33% of graphics were decorative. Whereas a border of leaves on a chapter about plants may be eye-catching, we did not consider it a visual display because it did not communicate information. Additionally, although textbook authors often provided a brief overview of the content formatted in a shaded box, it is the summary, not the visual organization, that adds to student learning. Therefore, we did not include these summaries.

Textbook Sample

This study focuses on the visuals in third and fifth graders' science and social studies textbooks. We selected textbooks because they are frequently encountered in K–12 classrooms, whereas, historically, other types of informational texts are often limited (Duke, 2000; Palincsar & Duke, 2004). Additionally, although researchers have examined the visuals in trade books (see Coleman & Dantzler, 2016), questions remain regarding whether those trade books are present in classroom libraries (Wright, Hodges, & Coleman, 2017).

In selecting textbooks, we began by identifying those adopted by highly populated states. This allowed us to assume that the textbooks would be present in many classrooms. Texas, for instance, is known for influencing textbook adoption nationwide because of its large population and subsequent buying power (Hiebert, 2005; Sadker, Zittleman, & Sadker, 2012). Furthermore, these states' textbooks have been used to build representative samples in similar content analyses (see Harmon, Hedrick, & Fox, 2000). In total, we included seven textbooks (see Table 1). To diversify our sample, we included textbooks adopted in states that both have (i.e., Florida and New York) and have not (i.e., Texas) implemented aspects of the Common Core.

We focused on upper elementary grades because at these grades, many children encounter their first standardized content exams. This testing emphasis suggests that it is critical to understand the cognitive demands of visuals for upper elementary students because they will be expected not only to comprehend their textbooks but also to derive content knowledge.

Table 1. Textbook Sample

| | | Adoption | | | |
| | | Grade 3 | | Grade 5 | |
Subject	Series	Texas	Common Core	Texas	Common Core
Science	*Science Fusion*	√	–	√	–
	Science Resources	√	√	√	√
Social studies	*myWorld*	√	√	√	√
	United States History	–	–	–	√

Our focus on science was influenced by national standards. Specifically, the Next Generation Science Standards (NGSS Lead States, 2013, p. 416) identified "developing and using models" as one of the habits of mind necessary to engage in scientific inquiry. Many scientific models include visual representations, and students need exposure to models before they can use and create them independently (NGSS Lead States, 2013). We included two series of science textbooks, *Science Fusion* (DiSpezio, Heithaus, & Frank, 2014a, 2014b) and *Science Resources* (Lawrence Hall of Science, 2014a, 2014b). Both series include textbooks for grade 3 and grade 5 (four science textbooks total) and cover topics in life, physical, and earth sciences. At the time of our analysis, *Science Fusion* had been adopted by Texas, whereas *Science Resources* was used by both Texas and Common Core states. Each book covered 1 year's worth of lessons.

Our decision to also investigate social studies texts is based on recommendations from the National Council for Social Studies, which identified that the ability to gather and evaluate visual sources is an important part of the College, Career, and Civic Life Framework (National Council for the Social Studies, 2013). The social studies set of textbooks contained three separate texts. We examined two series of books: *myWorld* (Alonzo, Bennett, Kracht, & White, 2016a, 2016b) and *United States History* (2013). At the time of this analysis, both Texas and Common Core states had adopted *myWorld*. To further diversify our social studies material, we also included a fifth-grade social studies textbook from Florida, *United States History*.

Coding Scheme

Following Fingeret (2012), we adopted the content/comparative approach for analysis (Strauss & Corbin, 1998). After comparing categories of visual displays from several studies (e.g., Coleman & Dantzler, 2016; Fingeret, 2012; Roberts et al., 2013), we created an exhaustive list (see Table A1). Next, we adapted the coding scheme from Fingeret to generate a list of detailed subtypes. For example, we identified diagrams as visuals displaying components of whole static relationships with labeled parts. Within diagrams, we identified seven subtypes, including bird's-eye view and cutaway diagrams. To further explicate, two authors independently drafted tentative definitions for each visual category and found representative examples. With the third author, we refined definitions (see Table A1 for the coding scheme).

We also developed a coding scheme to describe the visuals' functions. Initially, we coded visuals by their primary function (i.e., decorative, representative, organizational, interpretational, transformational; see Carney & Levin, 2002). If a visual had

several different functions (e.g., a simple diagram may be both representational and organizational), we coded the most prominent function determined by the surrounding text.

Fingeret (2012) coded any visuals that added new information as extensional, even if the primary function was representational. However, 64% of all visuals were extensional. To better capture and describe the functions, we coded extensions separately from graphical function. We coded the function of the graphic and then noted whether the visual added information distinct from the text. Modifying a scheme from Slough and McTigue (2013), we categorized these *connections* as either Level 1 or Level 2. We identified a visual as having a connection when it both represented the textual information and added new information. When reading a visual with a Level 1 connection, students would be able to easily interpret and connect the additional information to what they had read in the text. For instance, the caption may use slightly different verbiage, thus introducing new vocabulary while being explicitly tied to the text. However, a Level 2 connection would be more difficult to interpret, and the link between the text and the new information would require more inferencing. For example, in one science textbook, a passage introduced the concept of temperature, and the graphic presented ice in a glass with a caption asking the student to predict the water temperature. Engaging with this would require the student to have background knowledge about the properties of water in different phases.

Coding Procedures

To begin, the first and the second authors independently coded 100 pages of the same textbook. By comparing and discussing the results as a group, we clarified ambiguous items (e.g., the differences between cutaway and cross-section diagrams). Then, we generated examples and definitions for each visual type and subtype. Because our interest was in visuals that were intended to portray information, we only coded visuals in the content section of the textbooks. We excluded visuals in exercise sections (e.g., unit review exercises). However, within the main text, we coded when visuals asked children to complete a task, such as filling in a partially completed table. Such visuals were noted as *interactive*.

We treated captions as a part of visuals, and they were often critical to coding visual functions. For instance, if the visual and written text provided the same information but the caption added new details, the visual was coded as representational with a connection. For example, one social studies text introduced the establishment of Yellowstone National Park without mentioning the year it was established; however, this information was provided in the caption. We therefore coded the picture as a representational visual with Level 1 connection.

Next, we discussed and coded a subset of visuals. After the final consensus was reached, the first author independently coded the remaining textbooks. Items for which coding was uncertain were marked for further discussion. All authors met frequently to discuss progress and ambiguous visuals. This allowed the procedures to become increasingly more refined as the coding progressed.

To keep coding consistent, we did not expand our scheme until a new visual type appeared that demanded a different interpretative task for readers. We discussed these new types, and only after we reached consensus would we add a new type or a sub-

type to the coding scheme. For instance, after discussion, coders decided to add *comic strips* as a unique type, as we found these visuals in multiple texts, providing instructions, entertainment, or examples.

When a single visual was composed of one visual type overlaid on another, we coded such visual as *hybrid*. We coded the visual by its primary type, defined by identifying the prominent features most likely to attract a student's attention. An example would be a time line of inventions, with attached photographs to the side, which we coded as a hybrid time line.

Statistical Analysis

Using IBM SPSS Statistics for Windows (Version 23) software, we computed the visual types and functions. To address our second research question, we performed a chi-square test of independence to examine whether visuals in social studies and science textbooks were statistically different. According to Thompson (1988), a chi-square test can depict the data only as a whole picture and fails to report an individual cell's contributions to a statistically significant chi-square result. Therefore, we conducted a pair-wise post hoc test, using the Gardner (2001) procedure, to determine how the visuals differed. The Gardner procedure tends to minimize Type I error rates, thus allowing us to compare specific cells for statistically significant differences (MacDonald & Gardner, 2000).

Results

In total, we coded 3,844 visuals from seven textbooks. Visuals in science texts represent slightly more than 60% ($n = 2,324$) of the sample. In the following sections, we describe the types of graphics in the combined sample and then provide the results of the chi-square analyses, allowing us to detail how science and social studies visuals differ in form and function.

Types of Visuals

The data showed nine major visual types and 54 distinct subtypes (see Table 2). Of those nine categories, *photographs* (62.4%) were most prevalent. *General images* and *maps* were the second and third most represented, but the proportions of these two types were relatively small.

Although the total sample demonstrated a high frequency of photographs and general images, each discipline's textbooks contained different proportions. Table 3 lists the frequency and percentages of visual types in science and social studies textbooks and in the overall sample.

Results from chi-square tests showed that the types of visuals significantly differed between the two disciplines, $\chi^2(8, N = 3,844) = 647.165$, $p < .05$, with a medium effect size (Cramer's $V = .41$). Next, we conducted the post hoc analysis to determine which types demonstrated statistically significant differences. As suggested by Gardner (2001), we used a calculated p value with an adjusted alpha level (MacDonald & Gardner, 2000). Because there were 18 cells in the analysis, our alpha was set to .05 / 18, or .0028. The results showed a significant difference between the relative

Table 2. Frequency of Visual Categories and Types

Visual Type	Frequency	% All Visual Types	% Within Visual Types
Total	3,844	100	
Photographs:	2,397	62.36	100
Simple	2,220	57.75	92.62
Cluster	177	4.60	7.38
General images:	626	16.29	100
Fine art	272	7.08	43.45
Cartoon illustration	131	3.41	20.93
Computer-enhanced photograph	78	2.03	12.46
Realistic illustration	38	.99	6.07
Cartoon/thought-bubble text box	35	.91	5.59
Image cluster	29	.75	4.63
Magnified	16	.42	2.56
Logo	6	.16	.96
Scientific model	6	.16	.96
Stop motion	6	.16	.96
X-rays	4	.10	.64
Screenshot	2	.05	.32
Photograph of illustrations	2	.05	.32
Bird's-eye view	1	.03	.16
Characters (foreign language)	0	.00	.00
Radar	0	.00	.00
Maps:	203	5.28	100
Region	91	2.37	44.83
Flow	33	.86	16.26
Context	32	.83	15.76
Topographic	14	.36	6.90
Grid	12	.31	5.91
Simple	12	.31	5.91
Cluster	4	.10	1.97
Cartoon	2	.05	.99
Street	2	.05	.99
Landmark	0	.00	.00
Diagrams:	173	4.50	100
Simple	104	2.71	60.12
Cutaway	19	.49	10.98
Cross-section	17	.44	9.83
Scale, picture unit	16	.42	9.25
Scale, conventional unit	10	.26	5.78
Bird's-eye view	4	.10	2.31
Cutaway, cluster	3	.08	1.73
Illustrated equation	1	.03	.58
Flow diagrams:	173	4.50	100
Linear sequence	97	2.52	56.07
Tree	33	.86	19.08
Flow with cyclical sequences	26	.68	15.03
Web	11	.29	6.36
Flow with forked sequences	6	.16	3.47
Tables:	149	3.88	100
Column	65	1.69	43.62
Row and column	59	1.53	39.60
Row	14	.36	9.40
Pictorial	11	.29	7.38
Graphs:	71	1.85	100
Venn diagram	22	.57	30.99
Line	18	.47	25.35
Bar	15	.39	21.13
Pie chart	10	.26	14.08
Pyramid chart	6	.16	8.45

Table 2. (*Continued*)

Visual Type	Frequency	% All Visual Types	% Within Visual Types
Time lines:	29	.75	100
Simple	28	.73	96.55
Multiple	1	.03	3.45
Comic strips:	23	.60	100
Produced to provide instruction	18	.47	78.26
Provide entertainment or examples	5	.13	21.74
Elements:	350	100	—
Inset	122	35	
Key	122	35	
Hybrid	106	30	

proportions of visuals in science and social studies textbooks associated with diagrams, graphs, time lines, maps, tables, general images, photographs, and comic strips ($p < .0028$; see Table 4). Science textbooks were more likely to contain diagrams and photographs. By contrast, social studies texts had a higher proportion of graphs, time lines, maps, tables, general images, and comic strips, indicating a larger variety of graphics. Interestingly, there was no difference in the proportion of flow diagrams.

Considering complexity, there were 350 instances of additional elements (i.e., insets, keys, or hybrids; see Table 5). Because some visuals contained multiple elements, these data were not orthogonal and thus did not meet the assumptions necessary for a chi-square test (McHugh, 2013). However, science textbooks had a higher percentage of hybrid visuals and insets, whereas those used in social studies contained a higher percentage of keys.

Functions of Visuals

As detailed in Table 6, a majority of the visuals (60.9%) served a representational function (i.e., reflected information from the main text). Additionally, there were no transformational visuals and very few decorative visuals.

The chi-square test demonstrated a significant difference associated with functions, $\chi^2(3, N = 3,844) = 69.864$, $p < .001$, with a small effect size (Cramer's $V = .135$). We again adjusted our alpha levels for the post hoc test, in this case dividing the standard .05 by 8 to yield $p < .0063$. When examining each function, we found that the

Table 3. Frequency (Percentage) of Visual Subtypes

Visual Type	Science	Social Studies	Both
Total	2,324	1,520	3,844
Photographs	1,724 (74.2)	673 (44.3)	2,397 (62.4)
General images	206 (8.9)	420 (27.6)	626 (16.3)
Maps	31 (1.3)	172 (11.3)	203 (5.3)
Diagrams	159 (6.8)	14 (.9)	173 (4.5)
Flow diagrams	104 (4.5)	69 (4.5)	173 (4.5)
Tables	64 (2.8)	85 (5.6)	149 (3.9)
Graphs	25 (1.1)	46 (3.0)	71 (1.8)
Time lines	6 (.3)	23 (1.5)	29 (.8)
Comic strips	5 (.2)	18 (1.2)	23 (.6)

Note.—$\chi^2(8, N = 3,844) = 647.165$, $p < .05$, Cramer's $V = .410$.

Table 4. Visual Category Post Hoc Analysis Results

	Science	Social Studies	Total
Photographs:			
Count	1,724	673	2,397
Expected count	1,449.2	947.8	2,397.0
% within subject	74.2	44.3	62.4
Adjusted residual	18.7	−18.7	
p value	.0000	.0000	
General images:			
Count	206	420	626
Expected count	378.5	247.5	626.0
% within subject	8.9	27.6	16.3
Adjusted residual	−15.4	15.4	
p value	.0000	.0000	
Maps:			
Count	31	172	203
Expected count	122.7	80.3	203.0
% within subject	1.3	11.3	.8
Adjusted residual	−13.5	13.5	
p value	.0000	.0000	
Diagrams:			
Count	159	14	173
Expected count	104.6	68.4	173.0
% within subject	6.8	.09	4.5
Adjusted residual	8.7	−8.7	
p value	.0000	.0000	
Flow diagrams:			
Count	104	69	173
Expected count	104.6	68.4	173.0
% within subject	4.5	4.5	4.5
Adjusted residual	−.1	.1	
p value	.9203	.9203	
Tables:			
Count	64	85	149
Expected count	9.1	58.9	149.0
% within subject	2.8	5.6	3.9
Adjusted residual	−4.5	4.5	
p value	.00001	.00001	
Graphs:			
Count	25	46	71
Expected count	42.9	28.1	71.0
% within subject	1.1	3.0	1.8
Adjusted residual	−4.4	4.4	
p value	.00001	.00001	
Time lines:			
Count	6	23	29
Expected count	17.5	11.5	29.0
% within subject	.3	1.5	.8
Adjusted residual	−4.4	4.4	
p value	.00001	.00001	
Comic strips:			
Count	5	18	23
Expected count	13.9	9.1	23.0
% within subject	.2	1.2	.6
Adjusted residual	−3.8	3.8	
p value	.00015	.00015	

Table 5. Frequency (Percentage) of Elements in Textbooks

Element	Science	Social Studies	Both
Total	163	187	350
Insets	86 (52.8)	36 (19.3)	122 (34.9)
Keys	9 (5.5)	113 (60.4)	122 (34.9)
Hybrids	68 (41.7)	38 (20.3)	106 (30.2)

proportion of representative visuals differed significantly (see Table 7). Moreover, pair-wise tests demonstrated that the proportions of representational and organizational visuals differed significantly ($p < .0063$). Social studies textbooks contained a relatively larger proportion of organizational visuals, whereas science texts contained a larger proportion of representational visuals. The proportions of interpretational and decorative visuals were not significantly different.

Finally, we analyzed connection visuals. In total, 1,615 (42.01%) of the visuals contained new information. Among them, 73.4% provided information clearly linked to the text, which would be easy for students to interpret (see Table 8). The remainder (26.6%) were Level 2 and provided new information not concretely linked to the text.

The findings indicated that the proportions of Level 1 and Level 2 visuals in the science textbooks differed significantly from those in social studies, $\chi^2 (1, N = 1,615) = 22.771, p < .001$, with a small effect size of .119. Social studies textbooks contained relatively more Level 2 visuals (see Table 9), whereas science textbooks had more Level 1 visuals.

Discussion

Before strategically preparing students to navigate the visual complexity of informational texts, we need to understand modern academic texts. Additionally, as our understanding of disciplinary literacy becomes more comprehensive, we must consider the visual demands and conventions of graphics in each discipline. Therefore, we aimed to investigate the types and functions of visuals in U.S. third- and fifth-grade science and social studies textbooks. The results regarding the most common types and functions of visuals were consistent with the findings of Fingeret (2012), indicating that aspects of text design may be stable, despite changes in publication technology. Most notably, across both studies, photographs and general images (e.g., drawings, cartoons) were most common. In addition, the majority of the visuals were

Table 6. Frequency (Percentage) of Visual Functions

Function	Science	Social Studies	Both
Total	2,324	1,520	3,844
Representational	1,490 (64.1)	850 (55.9)	2,340 (60.9)
Interpretational	486 (20.9)	292 (19.2)	778 (20.2)
Organizational	295 (12.7)	349 (23.0)	644 (16.8)
Decorative	53 (2.3)	29 (1.9)	82 (2.1)
Transformational	0 (0)	0 (0)	0 (0)

Note.—$\chi^2 (3, N = 3,844) = 69.864, p < .001$, Cramer's $V = .135$. As there were no transformational visuals, the degrees of freedom were reduced to 3.

Table 7. Visual Functions Post Hoc Analysis Results

	Science	Social Studies	Total
Representational:			
Count	1,490	850	2,340
Expected count	1,414.7	925.3	2,340.0
% within subject	64.1	55.9	60.9
Adjusted residual	5.1	−5.1	
p value	.000	.000	
Interpretational:			
Count	486	292	778
Expected count	470.4	307.6	778.0
% within subject	20.9	19.2	20.2
Adjusted residual	1.3	−1.3	
p value	.197	.197	
Organizational:			
Count	295	349	644
Expected count	389.3	254.7	644.0
% within subject	12.7	23.0	16.8
Adjusted residual	−8.3	8.3	
p value	.000	.000	
Decorative:			
Count	53	29	82
Expected count	49.6	32.4	82
% within subject	2.3	1.9	2.1
Adjusted residual	.8	−.8	
p value	.424	.424	

representational in function—they concretely depicted the text information. In addition, our revised coding revealed notable findings regarding types and functions. In the following section, we present main findings organized by research question. Next, we examine differences between the two disciplines. Finally, we discuss implications and future research directions.

Types and Semantic Functions of Visuals

Types. To answer our first research question, we examined the visual frequencies. We found that photographs and general images are the most common visuals (62.4% and 16.3%, respectively). Interestingly, despite their prominence, photographs were not included in Vekiri's (2002) or Roberts and colleague's (2013) work—photographs were embedded within a more generic category of *captioned graphics*. Therefore, photographs may have received relatively limited attention, perhaps because the (false) assumption of objectivity and interpretation ease. Although photographs have long been associated with documentation of fact (Walden, 2012), social critics (e.g.,

Table 8. Frequency (Percentage) of Connection Visuals

Connection	Science	Social Studies	Both
Total	775	840	1,615
Level 1	611 (78.8)	574 (68.3)	1,185 (73.4)
Level 2	164 (21.2)	266 (31.7)	430 (26.6)

Note.—χ^2(1, N = 1,615) = 22.771, p < .001, Cramer's V = .119.

Table 9. Visual Connections Analysis Results

	Science	Social Studies	Total
Level 1:			
Count	611	574	1,185
Expected count	568.7	616.3	1,185.0
% within subject	78.8	68.3	73.4
Level 2:			
Count	164	266	430
Expected count	206.3	223.7	430.0
% within subject	21.2	31.7	26.6

Sontag, 1977) and journalists (Bissell, 2000) have challenged the assumption of objectivity by highlighting the role of the photographer and other gatekeepers (e.g., editors) who may modify images. However, as outlined in Callow's (2008) framework, young learners can be taught to assess visual features when viewing a photograph, as well as the metalanguage to describe the shot distance, angle, and character gaze. Particularly relevant for history texts, in the same manner that readers benefit from being taught to evaluate the sources used and the potential bias of the author (Shanahan & Shanahan, 2008), children should be taught to scrutinize photographs with a critical eye.

Visual complexity. It is also important to note the growing variety of subtypes within photographs, likely resulting from technological growth in digital photography and adding challenges of interpretation. Beyond simple photographs, we documented photo clusters, photo hybrids, and photographs with cutaways. Whereas a simple photograph may be cognitively accessible for a young reader, a photo with a cutaway becomes complex. For example, one image presented a cutaway diagram of the heart, embedded in a photograph of a child's body. This visual display is informative because it illustrates the heart's internal structure and location within the body. However, the multilayered composition requires students to discern and attend to different forms. According to Gerber, Boulton-Lewis, and Bruce (1995), younger readers tend to fixate on isolated components when processing graphics. Without sophisticated strategies, they often struggled with processing and integrating information from multiple sources (McTigue & Flowers, 2011). When both the density and intricacy of visuals increase, young learners may experience cognitive overload, leading them to simply ignore the visuals.

Semantic function. Most of these graphics served as representations (60.9%), meaning they provided a concrete example to support the text. According to dual coding theory (Clark & Paivio, 1991), linking abstract concepts to concrete examples may help students comprehend, retain, and recall newly learned information. However, we do not mean to imply that representational visuals are simply redundant with the text—more than 40% of the visuals coded added new information. Therefore, students should be encouraged to attend to visuals and extract information not available in the text. According to the cognitive theory of multimedia learning (Mayer, 2002), higher quality visuals both reinforce and extend the reader's knowledge. Unfortunately, previous work (e.g., Jian & Ko, 2017; McTigue & Flowers, 2011) indicates that students may not be fully attending to the graphics and risk missing key information from the text. This also has implications for assessment because many

high-stakes tests require students to interpret visual information. In a review of state science tests, 79.5% of items could not be answered correctly without examining the graphics (Yeh & McTigue, 2009).

Moreover, previous research indicated that the most advantageous graphics would be interpretational and transformational, as they would help the reader encode content in concrete and novel ways (Atkinson et al., 1999; Carney & Levin, 2002). Unfortunately, we did not find any transformational graphics in these textbooks. Our result may indicate a gap between research and text design. On a positive note, we coded the majority of visuals that added new information (73.4%) at the lowest level of connection, implying an explicit link between information in the visual and the text. Future research is needed to justify the implications of this finding, but it might indicate that the visual information would be relatively simple for young readers to integrate with the text. This finding is positive for the intended audience, as younger students have demonstrated difficulty perceiving the connections between information in two mediums (Jian, 2016).

Differences between Disciplines

Answering our second research question yielded interesting patterns. On average, science textbooks contained more diagrams and photographs than did social studies, with graphics most often serving a representational function. This finding is consistent with Fingeret's (2012) observations. When comparing our science textbook results with those of Coleman and Dantzler (2016), we see that both science trade books and textbooks contain high proportions of diagrams compared with other disciplines. These findings are expected because science often describes systems that are too small (e.g., microbiology) or too large (e.g., plate tectonics) to easily visualize or capture in a single photograph. Visual representations can help readers link the abstract process to a concrete example. Moreover, scientists self-report that they seek different representations of an idea while reading (Shanahan & Shanahan, 2008). For example, one chemist demonstrated a systematic back-and-forth reading process between the text and the picture in an effort to relate the two sources of information. To such scientists, the visuals were essential to communicating a concept. This finding may indicate that science textbooks for children are adhering to disciplinary expectations.

By contrast, social studies textbooks contained a greater diversity of visual forms. Because such texts incorporate "any of the specific disciplines that fall within social studies—history, geography, civics and government, economics, psychology, sociology, and anthropology" (Myers et al., 2002, p. 17), it is reasonable that the visuals should be similarly diverse. Additionally, social studies textbooks were more likely to contain organizational or interpretational visuals. These form and function outcomes are connected because tables and maps generally add to the organization of information.

Nevertheless, this variety presents challenges because different skills are needed for interpretation. For example, students need specific skills to navigate maps (Brugar & K. L. Roberts, 2014), time lines (Brugar & K. Roberts, 2014), and tables (Brugar & Roberts, 2015) in social studies. Roberts and Brugar (2014, p. 162) conclude that reading visuals in social studies texts "does not seem to be something that children are

likely to be able to do in the absence of carefully planned, intentional instruction." Therefore, the variety of visuals in social studies texts will likely challenge students' comprehension, and teachers need to model effective comprehension strategies.

Diversity within Science Textbooks

Although the study's purpose was to capture general trends in the use of visuals within modern textbooks, our work also revealed qualitative differences between the two science textbook series. The visuals in *Science Fusion* tended to be complex and to include many hybrid visuals, such as cutaway diagrams embedded in a photo or time lines combined with photos. In contrast, the social studies series used graphics in a more consistent manner, which may reflect disciplinary expectations. Therefore, it is should be acknowledged that publishers are making unique decisions regarding visual use.

Moreover, many visuals in *Science Fusion* required student interactions. For instance, this textbook frequently cued students to fill in the blanks on diagrams. Such an interactive design has not been noted in earlier research and is more typical of supplemental workbooks than textbooks. Thus, *Science Fusions* contains more interpretative as well as connection visuals, which might work to engage students. It is unclear, however, whether such a design would be helpful because textbook interactions may be limited. Pragmatically, schools reuse textbooks over several years and thus do not encourage students to write in them. However, with the increased use of digital texts, perhaps these sorts of activities will become more common.

Implications and Directions for Future Research

Our work has implications for future research in the fields of visual and disciplinary literacy. These findings can focus visual literacy instruction in elementary classrooms on the most common visual types. Without explicit instruction, students are unlikely to deepen their understanding of multimodal text (Peeck, 1993). Additionally, the increased use of composition with layers of images requires attention to help students navigate such complex forms.

As mentioned previously, although most elementary teachers use graphics in daily instruction, they rarely teach how to interpret or produce visuals (Coleman et al., 2011). Thus, instructional approaches for visual literacy should be included in teacher preparation and professional development (Metros, 2008). Drawing from established frameworks (see Callow, 2008), teachers can integrate visual literacy into authentic learning experiences. Students need to be made aware that visuals often are not redundant but contain information that may not be in the text. Modeling and instruction in these areas will most likely differentially benefit less skilled readers, who often do not develop sophisticated strategies on their own (Jian & Ko, 2017).

In addition to these general principles, students need discipline-specific instruction regarding how to read visuals in different genres. Roberts and Brugar (2017) recently explored students' understanding of four types of graphics in social studies textbooks. None of the students understood all aspects of these graphical devices, although there was a great variation across grades. For instance, while children often used maps outside of school, the purposes of maps in textbooks often differed from

those experienced in daily life. Students could "use this knowledge as a bridge to understand [the] more abstract purpose of using maps in textbooks" (Roberts & Brugar, 2017, p. 762), but proper application of background knowledge requires specific instruction and scaffolding. Because their study focused on four types of graphics, it would be valuable to extend this work to other common types of visuals. Our study documents the types of visuals that students will most often encounter in science and social studies textbooks, providing direction for future research.

Although convergent research suggests that graphical comprehension affects students' reading comprehension (Hannus & Hyönä, 1999; Mayer & Gallini, 1990; Roberts et al., 2015), a research gap is that few studies consider students' learning from authentic texts. Most research uses one graphic accompanying a block of text. Our work reveals a growing complexity of visual displays and layouts, suggesting that future studies should examine how young learners approach such layouts. Furthermore, studies describing how visual complexity increases across grade levels (in both textbooks and trade books) will be especially important in understanding the scaffolding that students need to comprehend graphics as they advance through the grades.

Further research is also needed to understand the utility of captions. Roberts and Brugar's (2017) study demonstrated that only 12.35% of elementary students could accurately or correctly name captions. When asked to create a caption, almost 20% of third-grade students misunderstood what a caption looks like. Overlooking captions is particularly concerning with more modern texts, such as the *Science Fusion* text, with extended captions blurring the line between adjunct visuals and the main text.

Finally, although we did not analyze e-books or examine electronic, particularly interactive, visuals that students encounter during online reading, the impact of this medium should be considered in future research. Mangen, Walgermo, and Brønnick (2013) found students had better comprehension after reading texts on paper than on computer screens. One explanation they offered is directly relevant for visuals, noting that "the fixity of text printed on paper supports reader's construction of the spatial representation of the text by providing unequivocal and fixed spatial cues for text memory and recall" (p. 66). Future investigations should extend this research to the visuals in computer-based informational texts.

Limitations

We collected a textbook sample that was purposeful and diverse, but it is not a random sampling. Likewise, although we chose textbooks on state-wide adoption lists, we do not know how many schools actually chose to invest in these texts. Additionally, although our coding scheme and procedures were based on previous research, we made modifications to better represent the visuals present in contemporary textbooks. We engaged in extensive collaboration to ensure reliability; however, future research will be required to fully validate this coding scheme.

Conclusion

This study provides researchers and teachers with an overview of the types and functions of visuals in contemporary science and social studies textbooks. Overall, we found nine major types and 54 subtypes of visuals, indicating that students frequently encounter a diverse range of visuals. The categories and functions of visuals differed in science and social studies. This finding leads us to the conclusion that visual literacy is not a generic approach but a set of discipline-specific skills. Additionally, current texts rely heavily on visuals and incorporate complex visual presentations that students may not be prepared to navigate. To support students' comprehension of informational texts and retention of discipline-specific content, researchers should develop instructional strategies that will develop students' visual literacy skills.

Appendix

Table A1. Full Graphical Type Coding Scheme and Definitions

Type	Description	Subtype	Definition
Comic strips	Traditional comic strips, coded frame by frame	Provide content	Typically produced by the textbook authors or publishers specifically for the textbook
		Provident entertainment/ examples	Typically produced elsewhere (e.g., newspapers) and reprinted in text
Diagrams	Graphics that model either the pieces or components of a whole system or static relationships between parts; generally includes labels	Bird's-eye view diagram	Shows organization from a top-down view
		Cutaway diagram	A 3-D picture where pieces are removed to make internal features visible
		Cross-section	Diagrams that include normally unseen or internal portions of an object or scene
		Illustrated equation	Mathematical or scientific formulas displayed visually
		Scale diagram (conventional)	Diagrams showing the size of something with a conventional unit of measurement for reference
		Simple diagram	Diagrams that do not feature any of the other defined characteristics
		Scale diagram (picture)	Diagrams showing the size of something in comparison with other visual information
Flow diagrams	Diagrams that model movement, change, or complex or hierarchical relationships; generally uses arrows to connect pictures or text	Cyclical sequences	Flow diagram that may or may not have a clear start, but circles back to the beginning
		Forked sequences	Flow diagram with an "either–or" choice within

Type	Description	Subtype	Definition
			the diagram. Not necessarily hierarchical
		Linear sequence	Flow diagram with clear start and end point
		Tree diagram	Flow diagram modeling hierarchical relationships or organization
		Web diagram	Flow diagram modeling multiple, intertwined relationships.
General images	Information of all kinds, sometimes symbolic, that require interpretation by the reader and may require the use of background knowledge; does not have lines with labels or words (as is common in diagrams)	Bird's-eye view	Shows image from a top-down view
		Cartoon illustrations	A simplified or exaggerated drawing of something
		Cartoon/thought-bubble text	Image of text that is stylized to look like a cartoon. Not embedded as part of a comic strip
		Characters	Images of foreign language writing systems
		Computer-enhanced image	Image with something added by computer, such as infrared mapping
		Fine art	Images of professional or historical art
		Image cluster	Multiple images used as part of one graphic
		Logo	An image that represents a company or organization
		Magnified image	An image of something that cannot be seen with the naked eye
		Photographs of illustrations	Photographic images of previously produced illustrations
		Radar image	Image produced using radar technology
		Realistic illustration	A drawing of the content that is realistic
		Scientific model	Image of a model used to illustrate a scientific concept
		Screen shot	Image created from the screen of a computer
		Stop motion	Series of images of the same object at different points in time
		X-rays	Images produced using X-ray technology to see inside of something (e.g., bones)
Graphs	Visually organize qualities or numbers	Bar graph	Graph in which values are represented by height or length of lines
		Line graph	Graph that uses line segments connected to data points to show data over time

Table A1. (*Continued*)

Type	Description	Subtype	Definition
		Pie chart	Circular shaped graph divided into sectors representing portions of a whole
		Pyramid chart	Chart in the form of a triangle, divided into sections, indicating a hierarchy.
		Venn diagram	Illustrates a relationship between sets, usually with a piece in common where the sets overlap
Maps	Geographical, sociological, or scientific information displayed on a representation of an area	Cartoon map	Unrealistic but visually appealing, map
		Context map	Political or geographical map of a region that serves to provide context for the information in the text
		Flow map	Map with arrows showing movement or relationships
		Grid map	Map with a grid overlay to define sections
		Landmark map	Map that primarily features the locations of specific landmarks
		Map cluster	Multiple maps used in one graphic
		Region map	Map of a larger area that defines specific regions
		Simple map	Map without any of the other defined characteristics
		Street map	Map focused on the names and locations of streets
		Topographical map	Map displaying the elevation of an area
Photographs	Photographs that do not fit the description of images or diagrams	Photo cluster	Multiple photographs used as part of one graphic
		Simple photographs	One photograph
Tables	Information organized in rows and columns	Column table	Table with a single column
		Pictorial table	Table that uses pictures to display information
		Row table	Table with a single row
		Row and column table	Table with several rows and columns
Time lines	Visually organize events in time	Simple time line	Shows events in a linear organization
		Multiple time lines	Two or more time lines showing events occurring at the same time in different contexts

Note

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