THE IMPACT OF VISUAL GRAPHICS ON K-12 STUDENTS' LEARNING ACROSS DISCIPLINES

A Dissertation

by

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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August 2018

Major Subject: Curriculum and Instruction

ABSTRACT

The primary focus of the dissertation is to investigate the impact of visual graphics on K-12 students' learning across disciplines. However, before this research line can be fully inquired, we should first understand the characteristics of graphics that students frequently encountered in classrooms and the current status of research. Therefore, this dissertation encompasses three connected studies: a) a content analysis of characteristics of graphics in elementary students' textbooks, b) a critical analysis of research in visual literacy, c) a systematic review on the impact of visual graphics on K-12 students' learning across disciplines.

The first study shows nine major types of graphics and 54 sub-types, indicating that students frequently encounter a diverse range of graphics. Additionally, the types and functions of graphics significantly differed between the two disciplines of social studies and science. My second study critiqued the methodology quality of current research regarding the effect of visual graphics on students' learning, identifying trends in rigor and in limitations. Additionally, models of research with high-level rigors were present to improve research in visual literacy. Finally, study three synthesized 44 pre-screened articles. Findings distinguished three types of visual graphics: author-provided, student-completed, and student-generated graphics and discussed their effectiveness on students' learning across disciplines. Findings show that simply using graphics do not guarantee a positive learning effect. To promote students' learning, teachers could provide support to guide them acquire multiple skills to integrate information from multimodal text.

DEDICATION

To my dissertation chair, Dr. Erin McTigue, for being my mentor that I aspire to be, and for being my teacher and friend that I respect; my appreciation is beyond expression.

To my mother, Weihong Zhang, for inspiring me to chase my dream and guiding me to be an independent, strong and positive person when facing challenges and obstacles.

To my father, Xiaohong Guo, for modeling diligence, generosity, and kindness that has driven force behind my passion and ambition.

To my husband, Guoqing Jian, for your understanding, encouragement, and support in this process.

ACKNOWLEDGEMENTS

Completing a doctoral degree needs determination, strength, and diligence, especially for an ELL student who chooses to study abroad. When facing challenges, I always tell myself "life is tough, but I am tougher", and I greatly appreciate my families, mentors, and friends who support and encourage me to persevere to the finish.

First, I would like to thank my families for loving, encouraging and supporting me through these four years. You offered me the opportunity of education and always inspire me to be a brave, ambitious and better person. Mom, I thank you for being my first teacher who motivated me to broaden my views, for offering me the opportunity to learn a second language since I was a kid, for showing me education is a career that is full of joy. Dad, thank you for modeling responsibility, work ethic, and diligence, and for comforting and encouraging me in my moments of stress and loneliness. My husband, Jian, thank you for passing me tissues and hugging me when I cried, and for cooking dinners for me when I was exhausted from work, for guiding me back when I occasionally veered off course.

I would like to thank my committee chair, Dr. McTigue for your wisdom, patient, selfless. I still remember the scenario: three years ago, I sit in your office, and I was nervous to introduce myself and express how I wish to be your student and join the team. At that time, I was very anxious as a doctoral student who was overwhelmed by coursework, concerned about research, and felt lost at the beginning of her third semester. You enlighten my life with your wisdom, professionalism, encouragement and kindness. Your mentorship has prepared me for the demands of academia: the skills to establish strong rapport with students and colleagues and the process to conduct high-quality research. I am honored to call you my teacher, mentor and friend.

I also would like to thank my committee co-chair, Dr. Matthews, for your guidance and support throughout my doctoral program. Especially, in my third year, I encountered challenges to succeed academically while balancing teaching demands. Thank you for providing me the opportunity to shadow your course and advise me to be a great teacher. Those moments are invaluable to this process. My committee members, Dr. Kuo and Dr. Luo, thank you for serving on my committee and providing valuable advice in this process, and for modeling efficiency, patience, and productivity, which encourage me to devote myself in academia.

I thank my research team members, Dr. Katherine Lauder Wright and Wendi Zimmer who made the data coding process efficient, and thank you for selflessly joining this project and sharing your knowledge of visual literacy and content-area literacy. My colleagues and friends, thank you for being constant sources of support. Finally, I thank every teacher of mine, who guides me to success.

To all of you mentioned above, and to those I may forget to list, I express my deepest gratitude. Thank you!

CONTRIBUTORS AND FUNDING SOURCES

Contributors

This work was supported by a dissertation committee consisting of Dr. Erin McTigue of the Norwegian National Centre for Reading and Reading Research, University of Stavanger, Dr. Sharon Matthews and Dr. Li-Jen Kuo of the Department of Teaching, Learning, and Culture, and Dr. Wen Luo of the Department of Educational Psychology.

The data depicted in Chapter II were partially double-coded by Dr. Katherine Lauder Wright of the Department of Literacy, Language, & Culture, Boise State University. The data depicted in Chapter III and IV and were partially double-coded by Wendi Zimmer of the Department of Teaching, Learning, and Culture.

All other work conducted for this dissertation was completed by the student independently.

Funding Sources

Graduate study was supported by a research fellowship from College of Education and Human Development.

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CHAPTER I

INTRODUCTION, DEFINITION OF KEY TERMS, & THEORETICAL PERSPECTIVES

Modern texts, both print and electronic formats, have become increasingly multi-modal and complex (Coleman & Dantlzer, 2010; Maeda, 2006). Yet, the literacy field continues to overemphasize the verbal (relative to visual) aspects of texts – a phenomenon documented by Winn 30 years ago as verbal bias (1987). He argued that an unfortunate byproduct of this bias is that students under-develop the mental structures endemic to visual processing. Schnotz (1993) later extrapolated that this verbal bias relegates graphics to a distant secondary role in the process of learning from texts. However, acknowledging current trends in communication, select theorists (e.g., Kress, 2003) contend that various modes of representation will soon replace language (e.g., emojis are already supplanting words in text messages) thus we need better understanding about how people learn from visuals in texts.

Despite using visuals for communication in all realms of life, our knowledge base for visual text comprehension is nascent and disorganized compared to verbal text comprehension. For example, while both theory and empirical research document a clear developmental progression in students' reading comprehension skills (e.g., Chall, 1983; Duke & Carlisle, 2011), we have limited analogous knowledge regarding the development of students' graphical literacy (Norman, 2010). Similarly, the extant research on the effect of using graphics (i.e., visual representations of information including, but not limited to, diagrams, pictures, and graphs) on reading comprehension contains discrepancies. While, theoretically, readers' benefit from having both verbal and visual sources of information (although effect sizes vary), there are certain situations where graphics have been shown to have no, or even negative, effects, on learners' comprehension (McTigue & Flowers, 2011; Hayes & Reinking, 1991). Additionally, the diversity of outcome measures quantifying learning from graphics adds additional variance to research findings, with Levie and Lentz's (1982) review including five unique forms of outcome measures, Peeck's (1987) review adding delayed recall, and Mayer's (1990) work focusing on application tasks. Therefore, the purpose of this work is to describe the impact of instructional graphics on learners' reading comprehension, and better understand under what conditions graphics most effectively facilitate students' learning. However, before this research line can be acquired, we should first understand the characteristics of visual graphics that students encountered in classrooms.

Thus, the present dissertation, a compendium of three unique studies, aims to explore the characteristics of graphic design, the impact of visual literacy for learning, as well as the research trend and quality in the field of visual literacy. Table 1 provides an outline of research questions answered by study one and a brief description of research methodologies.

Table 1. Study one research questions and research methodologies

Research Questions	**Research Methodologies**
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?	Descriptive Statistics (Frequencies)
2. Do the types and semantic functions of visuals differ in science and social studies textbooks? If so, how do they differ?	Chi-square test of independence and pairwise post-hoc test

Study one, *A Content Analysis of Visuals in Elementary School Textbooks*, informs the field by establishing a taxonomy of visuals in elementary school text. Next, it documents the form and function that visuals occupy in modern textbooks. Moreover, connected to principles of disciplinary literacy, this study examines the extent that types and semantic functions of visuals differ in science and social studies textbooks.

In Study Two, *Critical Analysis of Research on the Impact of Visual Literacy for Learning: Strengths, Weaknesses and Recommendations for Improvement,* I use the methodology of systematic literature reviews (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2010) and specifically the Methodological Quality Indicators (Risko et al., 2007) as a tool to code visual literacy study qualities in seven dimensions. Therefore, the first goal is to determine research with rigorous methodologies in the field of visual literacy (which will be further analyzed in Study Three). The second purpose is to synthesize strength and weakness of research methodology and propose recommendation for future endeavors. Table 2 outlines the research questions and methodologies regarding Study Two.

Table 2. Study two research questions and research methodologies

Research Questions	**Research Methodologies**
1. What are strengths and weakness in the body of research on the impact of visual literacy for learning?	Coding and analyze current research using Methodological Quality Indicators (Risko et al., 2007) and generate descriptive statistics (Frequencies)
2. What are recommendations for improvement for future research on visual literacy?	Qualitative analysis of included studies and generate themes

Finally, in Study Three, *a Systematic Review on the Impact of Visual Literacy for Learning across the Disciplines,* I aim to determine predominant themes in the research on the impact of visual literacy for learning across the disciplines. Furthermore, this study documents in what ways the incorporation of visual graphic tasks benefit K-12 students' content area learning.

Therefore, a methodological approach of systematic literature review (e.g., Risko, et al., 2008; Miller et al., 2016) is applied to evaluate the qualities of those studies and synthesize the findings of empirical research associated with the impact of visual literacy on K-12 students' learning across disciplines. Table 3 presents the research questions and methodologies that used in Study Three.

Table 3. Study three research questions and research methodologies

Research Questions	**Research Methodologies**
1. What are predominant themes in the research on the impact of visual literacy for learning across the disciplines?	Systematic review of included studies, descriptive statistics (Frequencies), and qualitative analysis.
2. In what ways does the incorporation of visual graphic tasks benefit K-12 students' content area learning?	

Combining the three studies, the present dissertation is translated into recommendations for research and practices for K-12 teachers. The primary purpose of this research is to inform future endeavors in the field in order to advance the state of research on visual literacy. By presenting the strengths and weakness of the research that has been published in the past fifteen years, I propose recommendation for improvement in terms of methodologies. Furthermore, the second goal is to connect theoretical perspectives to practice. The present work will inform K-12 teachers to understand the complexity of graphic design, students' learning process and outcome. Especially, understanding the principles of visual designs and challenges that students encountered will enable them to delivery effective instruction and better incorporate visual literacy with content area learning.

In the following sections, I will first define the important terms and constructs used throughout this dissertation. Secondly, I provide an overview of theoretical perspectives use of graphics in text. Finally, I conclude with the overall purpose statement.

Definitions of Key Terms

Before synthesizing the theoretical perspectives, the following section introduces several key constructs that used throughout this dissertation to ensure the consistency of the further discussion.

Visual Literacy

Robinson (1984) defined visual literacy as “the ability to communicate, understand, and produce communication visually”. Similar to this definition, visual literacy also refers to “the ability to read, interpret and understand information presented in pictorial or graphic image.” (Wileman, 1993, p.114) In this dissertation, visual literacy is defined as the ability to read, interpret and produce visual information, which also includes the ability to ethnically judge the accuracy, validity and the worth of visual information (Metros, 2008).

Disciplinary Literacy

Disciplinary literacy refers to distinct skills of reading, writing, speaking and listening. Disciplinary skills are relevant to content literacy, as they “specialized to history, science, mathematics, literature, or other subject matter” (Shanahan & Shanahan, 2008, p.44). It is the focus of secondary education. For instance, the skills that students apply to write a historical essay are different from that they used to produce a science report. More specifically, although both tasks required students to critically analyze sources of information, to write a scientific report, students mainly analyze the adequacy of studies’ methods, instrumentation and data sources. In contrast, historical summaries often derive from a combination of first and secondary sources and students not only need to determine the accuracy of information, but also consider the bias, qualifications and the position of the historian/author. Therefore, with one-size-fits-all reading strategies, students cannot fully complete the tasks unique to specific disciplines.

Narrative and Informational Text

Papas (1991) distinguished between narrative text and informational text by identifying the differences of linguistic pattern in the two text genres. Specifically, narrative text usually involved interpersonal understanding, such as how the characters achieve goals and how the plots connected. However, informational text had more varied organizational structures. For instance, it has specialized language characteristics such as general nouns and timeless verbs that are not common in other genres (Duke & Bennett-Armistead, 2003). In addition, the main purpose of informational text is to convey information, whereas the primary purpose of narrative text is to describe a story. Similar to this definition, Duke (2000) concluded several key features of informational text: (a) function to convey information, (b) factual content, (c) technical vocabulary, (d) general nouns and timeless verbs, (f) containing various types of text structure (e.g. cause and effect), (g) "classificatory and definitional material" (p. 205), (h) graphical elements. Based on Papas and Duke's work, informational text is defined in this study as a type of text that convey information about a phenomenon, event, situation or procedure (Fox, 2009) with the main purpose of inform readers.

Visual Graphics

Bertin (1983) defined graphics as monosemic representations. In other words, when readers interpret visual graphics, there is an intended one-to-one correspondence between the meaning and a visual graphic, in the manner of a labeled diagram. According to this definition, pictures and photograph are not considered as graphics, as they are polysemic, because the elements in pictures or photographs may signify more than one meaning. Therefore, the interpretation of pictorial representations (e.g. picture, photograph) is more subjective and ambiguous. However, in this study, visual graphics are defined as both monosemic and polysemic representations. We also recognize that visuals intended to be monosemic may not be interpreted by readers in the same way as the author, particularly when working with you learners. Additionally, the term “visual graphics”, “visuals”, “graphics” are used interchangeably in the study.

Author-provided Graphics

Author provided graphics are visuals that pre-constructed by authors and are most typical within texts. Students do not need to construct their own presentation during the reading process. For example, a pre-constructed visual graphic could be a flow map with color key represents the boreal bird immigration from Canada to U.S. each year. “When students learn from the preconstructed graphics, they generate their own understanding by internalizing information” (Vekiri, 2002, p.266).

Student-generated Graphics

Student-generated graphics require students to construct and represent what they learned from text. Generating a graphic often requires students’ higher order cognitive skills, specifically, students have to extract information from reading text, justify, apply and synthesize information and finally draw the visual graphics on their own. Interestingly, previous studies did not provide a clear distinction between author-provided graphics and students generated graphics, as some visual graphics may fit in both categories. For instance, students may be provided with an incomplete pre-drawn diagram. During the reading process, they need to seek and integrate information from both of verbal text and the diagram to complete labeling. Such graphics can be classified as both of author-provided graphics and students generated graphics. The overlap proportion was presented in the Venn diagram below.

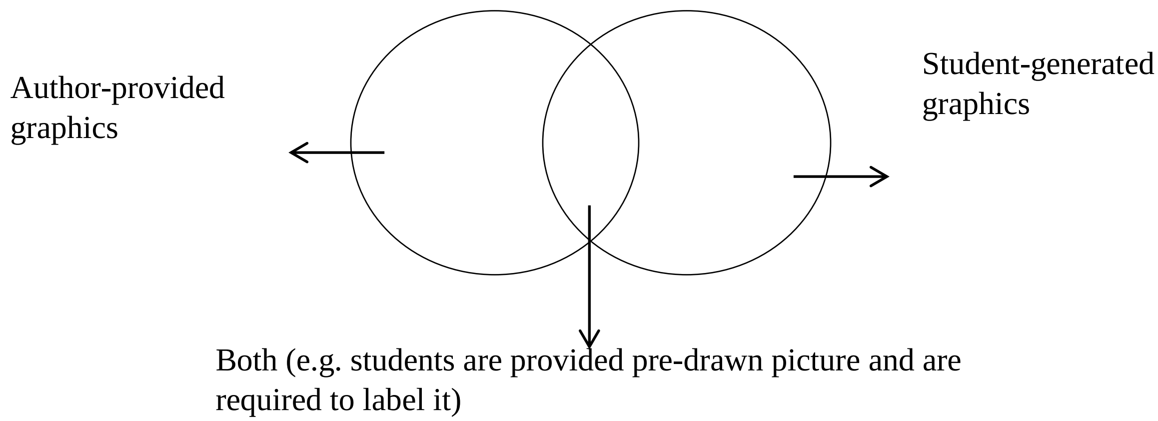

Figure 1. Venn diagram indicating the overlap proportion of author-provided graphics and student-generated graphics

Learning

Learning refers *to* “knowledge or skills acquired through study, experience, or being taught” (Learning, n.d.). Extended from definitions of learning, a learning outcome is described as significant and essential learning that learners have achieved. In 1956, Bloom categorized the cognitive domain of learning into six levels (from simplest to the most complex): knowledge, comprehension, application, analysis, synthesis, and evaluation. Anderson and colleagues (2000) later modified this taxonomy, and proposed a new classification of cognitive learning, which reflects a more active form of thinking: remembering, understanding, applying, analyzing, evaluating, and creating. This review will focus on the impact of visual graphics on cognitive domain of learning, specifically, how it facilitates students’ different levels of learning, such as conceptual learning, factual learning, recall, reading comprehension, problem-solving skills.

Reading Comprehension

Borrowing from the RAND Reading Study Group (2002), we conceptualize "reading comprehension as the process of simultaneously extracting and constructing meaning through interaction and involvement with written language" (p. 11). Expanding on this definition, we consider text to include words, images, sounds, designs, videos and formatting marks, in which these sources are codependent on the others (NCTE, 2005). We also argue that active and intentional thinking are involved in the interaction between the text and the reader (Durkin, 1978), which is influenced by the social-culture context.

K-12 Students

K-12 students refer to children are in schools, grade level from kindergarten to grade 12, approximately 5-18 years old. The terms students and learners are used interchangeably in discussion and are differentiated from adult and college or university learners.

Empirical Studies

"The studies are based on or verifiable by observation or experience rather than theory" (Emprical, n.d.). Research that analyzed data collected by observation, interview, quasi-experiment or experiment will be considered as empirical study in this dissertation.

Theoretical Perspectives for Use of Graphics in Text

The following section will introduce three theoretical perspectives that were widely used to explain the use of visual graphics in text.

Dual Coding Theory

Dual coding theory (DCT; Paivio, 1971, 1986) has frequently been used to justify including graphics with text (e.g., Hannus & Hyona, 1999; Verkiri, 2002). According to DCT, when learners encode information in both verbal and visual forms, they can more easily retrieve knowledge from their long-term memory, facilitating robust mental models. Applied to reading comprehension (Sadoski & Paivio, 1994), DCT predicts that text abstractness is a critical factor of complexity and thus reading comprehension. When approaching abstract texts, readers have relatively few mental images to support the language, and thus cannot capitalize upon non-verbal cognition. As such, abstract texts require more mental energy. According to DCT, adding concreteness (e.g., visuals) will enrich mental representations by adding visual specificity and facilitate reading comprehension. Second, visual displays can prompt learners to store information in two forms, visual and verbal. This dual coding reduces cognitive overload and aids memory because there are two pathways for the same information. For example, a science text may detail how water is comprised of hydrogen and oxygen through a verbal description and a molecular diagram. When later quizzed, the reader may forget the verbal description but be able to picture the diagram, and thereby recall the content.

DCT has been tested with both young and adult learners (Sadoski & Paivio, 2013). While not directly compared, both younger and older readers appear to benefit similarly from concreteness and struggle with abstractness. Regarding the design of graphical representations, because DCT posits that mental imagery assists in comprehension, more realistic graphics (such as photographs), may better promote comprehension. However, the benefit of realism may be situational. For example, Dwyer (1972) found that the degree of realism interacts with the amount of time and effort that the reader is willing to invest. Given time constraints, subjects found simple line drawings most useful, while in self-paced conditions they utilized the additional details offered by realistic representations.

Cognitive Theory of Multimedia Learning

Cognitive theory of multimedia learning (CTML; Mayer, 2001), is grounded in DCT but expanded to predict learning in multi-modal, particularly computer-based, environments which may include animation and narrations. CTML is often cited related to principles of multimedia design (Mayer, 2009). According to CTML, three essential processes contribute to the successful comprehension. In the first process, *selection*, learners extract relevant information from verbal text and graphics. Then, learners *organize* relevant information for comprehension and retention. In the last process, learners *integrate* these two models. Although CTML has been used extensively in research involving reading comprehension (e.g., Mayer & Gallini, 1990), it does not account for some critical aspects of reading comprehension (e.g., aspects of text quality) and more recent work focuses on interactive learning spaces.

Regarding specific predictions related to learning from graphics, CTML predicts that graphics will promote higher-level learning. For example, Mayer, Dyke, and Cook (1984) found positive effects of diagrams for comprehension of texts that dealt with systems (e.g., mechanical and biological). However, the presence of diagrams actually had negative effects on subjects' verbatim recall of the text. The authors hypothesized that readers use diagrams to help create a mental model of the concept, but during the phase of integrating information readers maintained only the ideas of the text rather than the actual syntax. Mayer (1989) again found evidence to support that diagrams specifically help retain higher-level explanatory information when reading scientific texts. The presence of illustrations resulted in improved skill transfer (answering application-type questions), but not verbatim recognition (Mayer, 1989). These findings are analogous to the work of Bieger and Glock (1986), in which students who used diagrams to assemble a device had a much higher assembly speed than those using only text, indicating better conceptual and spatial understanding. However, students who used only text for assembly had higher accuracy, indicating they gained more detailed knowledge from the text.

In reference to diagram design, CTML emphasizes the coherence principle (Mayer, 2009) in which extraneous information has been removed, thus focusing a learner's attention on the essential information. This work promotes designs such as flow charts, which focus on the essential components of a system and the relations within, and work to reduce information. In contrast, highly detailed and realistic portrayals (e.g., photographs) contain additional information that may distract a learner.

Regarding individual learner differences, CTML has been tested almost exclusively with college students (e.g., Mayer, 1990; Mayer & Sims, 1994), who represent both adult and highly skilled readers. Attempts to translate Mayer's principles to younger readers has been less successful (McTigue, 2009; Schrader & Rapp, 2016), thus bringing to question if skill and developmental age may interact with theoretical predictions. In total, CTML predicts that the principles of multimedia are consistent across learners, but there is limited empirical evidence to support that prediction.

Grammar of Visual Design

It is important to note that while distinct from each other, both CTML and DCT are derived from a cognitive/informational processing perspective. As such, a limitation of both is the assumption that human cognition can largely be generalized, thus providing a narrow consideration of individual differences related to culture and experience. Therefore, I also considered semiotics, specifically Kress and van Leeuwen's (1996) grammar of visual design, to present a broader, culturally situated, theory grounded in multimedia learning. According to Kress and van Leeuwen (1996), semiotics is the study of signs including print, visuals, and gestures, acknowledging that our understanding of signs is nested in culture systems. Therefore, semiotic theory predicts that learners with more experience with a type of visuals, perhaps due to age or culture, would derive more meaning. Following this logic, visuals that more closely resemble a learner's lived experience (e.g., a photograph) may be more meaningful than an abstract flow chart. Additionally, readers who have more experience with the conventions of school texts may be more adept at managing the endemic graphics. For example, Wheeler and Hill (1990) cautioned that diagrams which reduce complexity and realism in favor of simplicity are particularly difficult for children.

In conclusion, DCT and CTML explained students' perception of multimodal text from a cognitive perspective, whereas grammar of visual design considered visual literacy as an experience in social and cultural context. These theoretical frameworks allow me to understand the underlying principles of the effect of visual literacy on learning.

Purpose

In summary, this dissertation encompassed a content analysis on graphics in elementary school text and two types of reviews as follows: methodological and outcome. First, as aforementioned, the purpose of the content analysis is to better capture the characteristics of visual graphics in elementary school texts in terms of types and functions. Second, in regarding to methodology, this study aims to specifically consider the methodological qualities of research in visual literacy and provide implication for researchers in the field. Finally, regarding outcome, by using evidence provided by empirical studies, the present review aims to explain the roles of visual graphics in learning with a specific focus on different levels of learning in K-12 context and provide tentative explanation about findings. The review will consider the extent that graphics facilitate different learning outcome.

CHAPTER II

A CONTENT ANALYSIS OF VISUALS IN ELEMENTARY SCHOOL TEXTBOOKS

Recently the Common Core standards, as well as a growing emphasis on STEM education in elementary school, have called for informational books to play a progressively prominent role in literacy instruction. Accordingly, students need highly developed skills in genre conventions and structures to navigate these informational texts (Duke & Billman, 2009; Pappas, 2006). However, beyond the text structures and features, researchers have noted the number and complexity of visuals in elementary textbooks have increased. Textbooks have also morphed into more visually engaging formats, and as a result constructing meaning from texts now not only relies on comprehending the words, but also the visual displays (McTigue & Flowers, 2011; Coleman & Dantzler, 2016; Walpole, 1998).

Sufficient evidence demonstrates that well-designed visuals can improve learning of informational text (e.g. Hannus & Hyona, 1999; Haring & Fry, 1979; Mayer & Gallini, 1990) and that visual comprehension represents a unique contribution to reading comprehension (Roberts, Norman & Cocco, 2015). However, not all visuals are created equal, and the decoding skills required to comprehend a visual depends upon many factors, particularly its format and presentation (Palincsar & Duke, 2004). For example, reading a timeline in a traditional social studies book requires the reader to understand that a line and arrows represent a chronological passage of time. By contrast, lines and arrows in a diagram of the water cycle represent the movement of water, a distinctively different construct. Clearly, young readers must receive explicit instruction in how to decode visuals. Supporting students' comprehension of these visuals will likely improve overall informational text comprehension (Guo et al., 2017).

The implementation of Common Core State Standards has led educators to pay more attention to text complexity. Text complexity differs from text difficulty, in that complexity refers to the features of a passage that are independent from the reader, whereas text difficulty describes the challenge a text for a particular reader (Cunningham & Mesmer, 2014). While visual presentation of information will certainly influence text complexity, to date, limited research has systematically examined the quality, characteristics, and cognitive demands of these visuals in the textbooks readers encounter in science and social studies. Fingeret (2012) conducted a systematic review of visuals in science and social studies textbooks for her dissertation research, however, the coding method regarding to functions of graphics is problematic and findings are now dated. Similarly, Slough and colleagues (2010) conducted an analysis of visuals in textbooks, but this study was limited to 6th grade science textbooks used in Texas. More recently, Coleman and Dantzler (2016) completed an extensive analysis of visuals in science trade books. However, their analysis ended in books published in 2007 and did not include textbooks. Textbooks represent a distinct genre and unique formatting, and thus generalizations cannot be made from trade books.

Because visuals often impart information unique from the written text, it is valuable to investigate the types of visuals present in contemporary textbooks, as well as the degree of integration between visuals and text in elementary school textbooks. The purpose of this study, therefore, was to examine the visuals present in textbooks used in elementary science and social studies classrooms and analyze their function and form. Such findings will allow researchers and teachers to determine the characteristics of visuals students most frequently encounter, and develop instructional and intervention strategies to support students' comprehension of these informational school texts.

Literature Review

Visual Literacy is an interdisciplinary area that spans multiple research fields including communication, educational psychology, and arts, literacy, and STEM education. While researchers have not agreed upon a single taxonomy across fields, visuals have been classified by a) form (i.e., type), b) function, and c) quality. In this section, I will explore each of these classification schemes, focusing on how previous researchers have used them to describe visuals. Following this, I discuss the purpose of visuals in K-12 textbooks, and explore the existing research examining the efficacy of visuals in science and social studies textbooks.

Theories underlying Visuals' Use in Instructional Materials

The classification schemes I use to describe visuals are grounded in three theoretical perspectives. In a systematic review, Vekiri (2002) proposed these three theories to explain the benefits of visuals on learning: Dual Coding Theory (Sadoski & Paivio, 2003; Clark & Paivio, 1991), Visual Argument Hypothesis (Waller, 1981; Larkin and Simon, 1987) and the Conjoint Retention Hypothesis (Kulhavy, Lee, & Caterino, 1985). While each theory is unique, all three are based on the information processing approach to learning, which assumes that working memory is a limiting factor for learning. Thereby, the addition of visuals to text is more useful because it provides two routes (verbal and nonverbal) for readers to encode and retrieve information. Compared with verbal information, visuals are more concrete. Therefore, when provided with visual information, students can more easily retrieve knowledge from their long-term memory, as it reduced their cognitive load. Hence, the presence of visuals along with text has additive effects on learning (Hannus & Hyona, 1999; Norman, 2010; Norman, 2012).

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 by different types of visuals, while being broad enough to make generalizations about the findings. Researchers have struggled to strike such a balance. In the aforementioned review, Vekiri (2002) also summarized four common types of visuals, each with unique conventions for communication: diagrams, graphs, maps, and (network) charts. With some overlap with Vekiri's taxonomy (2002), Fingeret proposed eight types of visuals with 59 discrete subtypes. This classification is very comprehensive, but can be cumbersome in practice. Drawing on Figureret's work, Roberts and colleagues (2013) specify visuals into eight types: captioned graphics, diagram, flowcharts, graphs, inset, maps, tables, and timelines. This scheme was particularly useful to the field as I provided clear definitions and examples for each of their types.

Because identifying specific types of visuals can be problematic, many researchers have chosen to focus on the numerous ways visuals function in information texts (e.g., Carney & Levin, 2002; Concannon, 1975; Fingeret, 2012; Hegarty, Carpenter, & Just, 1996; Levin, Angvin & Carney, 1987). While multiple classification systems exist, 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 picture presented in the preface of a science textbook). *Representational* visuals show the literal meaning of the text in a visual form (e.g., a picture of a volcano in a section describing volcanic eruptions). *Organizational* visuals classify and organize information in text (e.g., a table summarizing the data collected from an experiment). This function of visuals is essential in informational textbooks, as they improved students' recall of information (Armbruster, Anderson, & Meyer, 1991). *Interpretational* visuals explain abstract concepts or ideas in a more concrete way (e.g., a diagram showing light from the sun feeding a plant to explain photosynthesis). *Transformational* visuals are mainly used to enhance readers' retention of content by presenting the information in a more vivid way (e.g. an atom depicted in a shape of pen to provide a mnemonic device for *p*roton, *e*lectron, and *n*eutron). More recently, Fingeret (2012) modified this classification by adding the sixth category, *extensional* visuals, which provide supplemental information not explicitly included in the text.

Impact of Visuals on Learning

Despite theoretical ground, existing research has come to differing conclusions regarding the efficacy of visuals in textbooks. Many of the previous studies focus on reading outcomes after studying a visual, such as how a diagram facilitated students' reading comprehension and memory (e.g. Hannus & Hyona, 1999; Haring & Fry, 1979), or its impact on students with different reading abilities. For instance, some studies have demonstrated that including visuals with texts is more beneficial for higher-ability children than their struggling peers (Roberts et al, 2013). One explanation for this phenomenon is that some students have more background experience reading visuals, and thus are strategic processors and tend to spend more time on pertinent segments of text and visuals (Hannus & Hyona, 1999; Roberts et al., 2013). Alternatively, switching between two sources of information may cause children already burdened by the cognitive load of the text to be further confused, thus limiting the efficacy of the visual. For instance, Jian (2016) found that children have limited capacity to integrate information presented in visuals with that in texts, which results in poor reading comprehension.

However, other research contradicts this perspective, showing visuals are also beneficial for low achieving readers' comprehension (Hayes & Reinking, 1991; Holmes, 1987). For instance, Holmes' (1987) research revealed that although more skilled readers scored significantly higher when processing text, there were no differences between the skilled and less-skilled readers in comprehending text accompanied by pictures. Students in both groups performed significantly better when provided with adjunct pictures rather than only studying written text.

More recently, a meta-analytic study (Guo et al., 2017) revealed that, in comparison with reading texts alone, the inclusion of visuals has a small to medium positive effect on students' reading comprehension, with an overall effect size of 0.36. Additionally, when comparing visual types, pictures had a stronger impact on comprehension than pictorial or relational diagrams. These findings suggest that the type of visual influences the impact on reading comprehension. However, I also found that numerous studies did not provide students explicit instruction in how to read the visual before conducting the experiment – that is, participants relied on existing visual comprehension skills to interpret the text. These findings suggest that if we can provide children with explicit instruction in interpreting specific types of visuals, they may be able to derive the benefits of visuals and reduce inefficiency of processing two sources of information, and therefore support their holistic text comprehension. However, before this line of inquiry can be followed, we must determine the characteristics of visuals are present in contemporary textbooks so we can better understand the types of training and intervention children require.

Purpose and Research Questions

Fingeret (2012) first addressed this issue in her dissertation by analyzing the visuals present in eight second- and third- grade science and social studies textbooks, published between 2003 and 2007, finding that the majority (66.9%) of visuals were simple photographs, and nearly 64.2% functioning as extensional visual displays. Although she established strict guidelines for analysis, Fingeret (2012) acknowledged that the coding process was potentially problematic. For instance, any information in a table or a flow chart was classified as an extension of text; however, the primary function of tables is organizational. Thus, the coding system required revisiting.

Moreover, the release of the Common Core Standards for English/Language Arts in 2009 and Next Generation Science Standards in 2013 addressed the important roles of graphics in learning from textbooks. Even where Common Core Standards have not been adopted, many state standards have recently been revised in similar directions, or are currently being reconsidered (e.g., see Texas Education Association, 2015). Thus, before researchers can make recommendations to support students' visual literacy, we must examine currently adopted textbooks to understand what kinds of visuals students are encountering.

Therefore, the purpose of the current study is to evaluate the visuals present 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 & Hiebert (2014), I developed and utilized a qualitative system for coding the visuals and describing how they may add to text complexity. My research is guided by the following 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, I analyzed visuals in informational texts, or a text "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), I defined “visuals” as graphical displays**,** which are not limited in format to diagrams, maps, graphs, and tables. Any photographs, images, or illustrations in the informational text should also be understood as meaningful visual signs, and therefore were also considered as visuals. A visual may contain some text, such as labels on a regional map, or a caption, which present supplemental information to the picture; however, the main source of information comes from visual, rather than textual, presentation.

Not all visuals in textbooks meet this definition (Fingeret, 2012). For example, a colorful margin or a frame that decorates the text may be eye-catching, but it is not considered a visual display because it is strictly decorative and not communicating information. Additionally, while 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, for the purpose of the present study I did not include these as part of the visual analysis.

Textbook Sample

This study focuses on the visuals contained in 3rd and 5th graders’ science and social studies textbooks. I selected textbooks because they are frequently encountered in K-12 classrooms, and, historically, other types of informational texts have often limited in elementary grade classrooms (Duke, 2000; Palincsar & Duke, 2004). I focused on 3rd and 5th grade students, as these grades are when many children are encountering their first standardized exams. Furthermore, the well-documented shift from “learning to read” to “reading to learn” generally occurs around third grade (O’Brien, 2008). This suggests that it is critical to understand the cognitive demands of visuals for these upper-elementary students, as they will be expected to not only comprehend their textbooks, but derive content knowledge from them.

In order to diversify my sample and be able to generalize results, I chose to include textbooks adopted both in states that are implementing the Common Core and in those that are not. According to Hiebert (2005) and Sadker, Zittleman, and Sadker (2012), Texas, although not adopting the Common Core standards, is known for influencing textbook adoption nationwide due to its large population and buying power. Texas textbooks have also been used to build representative samples in similar content analyses, such as Harmon, Hedrick, and Fox's (2000) work examining vocabulary instruction in social studies texts. Therefore, I used the adopted textbooks from Texas to represent the non-Common Core portion of the sample. In total, I included seven textbooks in this study (see Table 4).

Table 4. Textbook sample

	3rd grade			5th grade		
Subject	**Series**	**Texas Adoption**	**Common Core Adoption**	**Series**	**Texas Adoption**	**Common Core Adoption**
Science	*Science Fusion*	√		*Science Fusion*	√	
	Science Resources	√	√	*Science Resources*	√	√
Social Studies	*My World*	√	√	*My World*	√	√
				United States History		√

I included two series of science textbooks, *Science Fusion* (DiSpezio, Heithaus, & Frank, 2014a, 2014b) and *Science Resources* (Lawrence Hall of Science, 2014a, 2014b). Both of these series included a textbook specifically for grade 3 and grade 5 (four science textbooks total), and covered topics in life, physical, and earth sciences. At the time of our analysis, *Science Fusion* had been adopted by Texas, while *Science Resources* was used by both of Texas and Common Core states. Each book covered a year's worth of lessons.

The social studies set of textbooks contained three separate texts. I first examined two series of books, namely *My World* (Alonzo, Bennett, Kracht, & White, 2016a; 2016b) and *United States History* (2013). At the time of this analysis, both of Texas and Common Core states had adopted *My World*. To further diversify social studies materials, I also selected Florida's adopted social studies textbook, *United States History* (2013), used in grade five. Like Texas, Florida is another large state, which influences textbook development decisions. However, unlike Texas, Florida has adopted the Common Core Standards.

Coding Scheme

Modeling after Fingeret (2012), I adopted the content/comparative approach for analysis (Strauss & Corbin, 1998). After comparing the different categories of visual displays in several studies (e.g., Fingeret, 2012; Roberts et al., 2013), I created a list of all possible types: diagrams, flow diagrams, graphs, timelines, maps, tables, images, photograph and comic strips. Next, I generated a list of detailed sub-types for further analysis, adapted from Fingeret's (2012) study. For example, I identified diagrams as visuals displaying components of whole, static relationships with labeled parts. Within diagrams, I identified seven discrete sub-types including bird's eye view and cut-away diagrams.

To further define the coding scheme, I also invited other researchers for discussion. We independently drafted definitions for each type and sub-type of visual, and found representative examples. Working with the third researcher, we discussed each and came to common understandings and definitions. This coding scheme with definitions is available in Appendix.

We also developed a coding scheme to describe the functions of the visuals. We began Fingeret's (2012) process and made modifications to address the limitations of this previous work. First, the visuals were coded 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 have the function of representation and organization), we coded the most prominent function as determined by the surrounding text.

Fingeret coded any visuals that added any new information as “extensional,” even if the primary function was representational. However, in her results 64% of all visuals were extensional. To better capture and describe the function of the visuals, we separated this into two categories. We first coded the primary function of the graphic, and then noted whether the visual added information unique from the text. We categorized these *connections* as either a level 1, 2, or 3 connection. We identified a visual as having a connection when it both represented the information in the text and added new information. Frequently, students would need to make connections between the visual and the related text. When reading a level 1 connection visual, students would be able to easily interpret and connect the additional information to what they had read in the text. However, an image with a level 2 connection would not be as easy to interpret, and the link between the text and the new information would be less concrete and require more inferencing on the part of the reader. Finally, a level 3 Connection would indicate a visual that would require extensive background knowledge for a student to interpret.

Coding Procedures

To begin, the second researcher and I coded 100 pages of the same science textbook independently. By comparing and discussing the results as a team, we clarified some ambiguous items (e.g. the differences between cut-away diagram and cross-section diagram). Then, as previously discussed, we generated examples and definitions for each visual type and sub-type.

As my interest was in those visuals intended to portray information, I only coded visuals in the content section of the textbook. Visuals presented in the exercises sections (e.g. formative assessments, unit review exercises) were excluded. In the coding sheet, I created a new column to note visuals that asked children to interact with or complete the visual. For example, if the text instructed students to fill out the table, I made note of this on our coding sheet.

I also decided to code captions as a part of visuals, as research indicated that children often do not explicitly read the captions (Hannus & Hyona, 1999). Captions were often critical to coding as they provide evidence to help identify the functions of a visual. For instance, if the visual provided the same information found in the written text, but the caption added some new information, the visual was coded as "representational” with a “connection”. As an example, one social studies text introduced the establishment of a U.S. 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, I coded visuals in the remaining textbooks independently. Uncertain items were marked during coding for further discussion. All three researchers met frequently to discuss the progress and make decisions on ambiguous visuals. This allowed the procedures to become increasingly more refined as the coding progressed.

To keep coding consistent, we did not expand the coding until a new visual type appeared that presented a different interpretative task for readers. These new types were discussed, and only when the consensus was reached, we would a new type or a sub-type be added into the list of visuals in coding scheme. For instance, after discussion, coders decided to add “Comic Strips” as unique type, which were found in multiple texts providing instructions, entertainment, or examples.

One unexpected finding was that many of the visuals included more than one type of visual. I called these *hybrid visuals*, and when they appeared in textbooks I coded the visual by its primary type, and noted the hybrid nature. I defined the primary type by identifying the clearest prominent feature that would most likely attract a student's attention. An example would be is a diagram with labels, presenting root systems of a tree under the earth, with an attached photograph of trees from above ground.

Through coding procedures, I also noted three visual qualities that appeared in multiple types of visuals and influenced our coding. First, visuals contained an *inset* when a secondary visual overlaid the main visual, specifically showing an enhanced image of a piece of the main visual. For instance, a map of a large area (such as a state) may have an inset containing a smaller, magnified map of a particular region (such as a city). Secondly, many visuals also contained a *key,* which described how symbols or colors represented content in a visual. Third, as previous mentioned, many visuals were hybrids. Quite often, a single visual would contain multiple of these characteristics. Rather than making a separate sub-type under each type of visual, we made a general category named "elements" and simply noted whether these qualities were present.

Statistical Analysis

To examine the types and functions of visuals present in the textbook sample I computed the frequencies for each. To address the second research question, I performed a chi-square test of independence to examine whether visuals in social studies and science textbooks are statistically different. According to Thompson (1988), a chi-square test can only depict the data as a whole picture and it fails to report individual cell's contributions to a statistic significant chi-square result. Therefore, I conducted a pairwise post-hoc test using the Gardner (2001) procedure to determine how the visuals differ in science and social studies textbooks. I chose the Gardner procedure for the post-hoc analysis because it tends to minimize Type I error rates and allowed us to compare specific cells for statistically significant differences (MacDonald & Gardner, 2000). I analyzed the data using SPSS version 23.

Results

In total, I coded 3,844 visuals found in the seven textbooks. Visuals in science texts represent slightly more than 60% of this total (*n* = 2,324), and visuals from social students texts comprised the remaining of the sample (*n* = 1,520). In the following sections, I first describe the types of graphics found in the combined sample. Next, I provide the results of the chi-squared analyses, allowing us to detail how visuals in science and social studies textbooks differ in both form and function.

Types of Visuals

Overall, the data showed nine major visual types and 54 distinct sub-types. Of those nine categories, *photographs* (62.4%) were the most prevalent visuals. Findings show that *image* and *map* were the second and third most represented visuals, but the proportions of these two types (16.29% and 5.8%, respectively) were relatively small. Table 5 shows all specific visual categories and the number and percentage of those categories.

Table 5. Frequency of visual categories and types

Visual Types	**Frequency**	**Percent (All Visual Types)**	**Percent (Within Visual Types)**
TOTALS	3844	100	
Photographs	2397	62.36	100
Simple photographs	2220	57.75	92.62
Cluster of photographs	177	4.60	7.38
General Images	626	16.29	100
Fine art	272	7.08	43.45
Cartoon illustrations	131	3.41	20.93
Computer enhanced photograph	78	2.03	12.46
Realistic illustration	38	0.99	6.07
Cartoon/thought bubble text box	35	0.91	5.59
Image cluster	29	0.75	4.63
Magnified image	16	0.42	2.56
Logo	6	0.16	0.96
Scientific model	6	0.16	0.96
Stop motion	6	0.16	0.96
X-rays	4	0.10	0.64
Screenshot	2	0.05	0.32
Photograph of illustrations	2	0.05	0.32
Bird eye view	1	0.03	0.16
Characters (foreign language)	0	0.00	0.00
Radar image	0	0.00	0.00
Maps	203	5.28	100
Region map	91	2.37	44.83
Flow map	33	0.86	16.26
Context map	32	0.83	15.76
Topographic map	14	0.36	6.90
Grid map	12	0.31	5.91
Simple map	12	0.31	5.91
Map cluster	4	0.10	1.97
Cartoon map	2	0.05	0.99
Street map	2	0.05	0.99
Landmark map	0	0.00	0.00
Diagrams	173	4.50	100
Simple diagram	104	2.71	60.12
Cut-away diagram	19	0.49	10.98
Cross-section	17	0.44	9.83
Scale diagram picture unit	16	0.42	9.25
Scale diagram conventional unit	10	0.26	5.78
Bird's eye view diagram	4	0.10	2.31
Cut-away diagram cluster	3	0.08	1.73
Illustrated equation	1	0.03	0.58
Flow diagrams	173	4.50	100
Linear sequence	97	2.52	56.07
Tree diagram	33	0.86	19.08
Flow diagram with cyclical sequences	26	0.68	15.03
Web diagram	11	0.29	6.36

Table 5. Continued

Visual Types	Frequency	Percent (All Visual Types)	Percent (Within Visual Types)
Flow diagram with forked sequences	6	0.16	3.47
Tables	149	3.88	100
Column table	65	1.69	43.62
Row and column table	59	1.53	39.60
Row table	14	0.36	9.40
Pictorial table	11	0.29	7.38
Graphs	71	1.85	100
Venn diagram	22	0.57	30.99
Line graphs	18	0.47	25.35
Bar graphs	15	0.39	21.13
Pie charts	10	0.26	14.08
Pyramid charts	6	0.16	8.45
Timelines	29	0.75	100
Simple timelines	28	0.73	96.55
Multiple timelines	1	0.03	3.45
Comic Strips	23	0.60	100
Produced to provide instruction	18	0.47	78.26
Provides entertainment or examples	5	0.13	21.74
Elements	350	100	
Insets	122	35	
Keys	122	35	
Hybrids	106	30	

While the total sample demonstrated a high frequency of photographs and images, each discipline's textbooks contained different proportions of these types of visuals. Table 6 lists the frequency and percentages of visual categories in science and social studies textbooks.

Table 6. Frequency and percentages of visual sub-types

Visual Type	Science	Social Studies	Both
TOTALS	2324	1520	3844
Photographs	1724 (74.2%)	673 (44.3%)	2397 (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 (0.9%)	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%)
Timelines	6 (0.3%)	23 (1.5%)	29 (0.8%)
Comic Strips	5 (0.2%)	18 (1.2%)	23 (0.6%)

X^2 *(8, N* = 3844) = 647.165, $p < 0.05$, *Cramer's V = 0.410*

Results from chi-square tests showed that the types of visuals significantly differed between the two disciplines, X^2 (8, N = 3844) = 647.165, $p < 0.05$, with a medium effect size, 0.41. Next, I conducted the post-hoc analysis to determine which categories demonstrated statistically significant differences between the two disciplines. As suggested by Gardner (2001), I used calculated p value with adjusted alpha level (MacDonald & Gardner, 2000). In this case, because there were 18 cells in the analysis, the alpha was set to 0.05/18, or 0.0028. The results of pairwise comparison showed that there is a significant difference between the relative proportions of visuals in science and social studies textbooks associated with the following types: diagrams, graphs, timelines, maps, tables, images, photographs and comic strips, $p <$ 0.0028, (See Table 7). Science textbooks were more likely than social studies textbooks to contain diagrams and photographs. By contrast, social studies texts had a higher proportion of graphs, timelines, maps, tables, images, and comic strips. Interestingly, there is no significant difference between science and social studies textbooks associated with the proportion of flow diagrams, which were mainly used for organizing information.

Table 7. Visual category post-hoc analysis results

		Science	Social Studies	Total
Photograph	Count	1724	673	2397
	Expected Count	1449.2	947.8	2397.0
	% within Subject	74.2%	44.3%	62.4%
	Adjusted Residual	18.7	-18.7	
	P value	0.0000	0.0000	
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	0.0000	0.0000	
Maps	Count	31	172	203
	Expected Count	122.7	80.3	203.0
	% within Subject	1.3%	11.3%	0.8%
	Adjusted Residual	-13.5	13.5	
	P value	0.0000	0.0000	
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	0.0000	0.0000	
Flow Diagrams	Count	104	69	173
	Expected Count	104.6	68.4	173.0
	% within Subject	4.5%	4.5%	4.5%
	Adjusted Residual	-0.1	0.1	
	P value	0.9203	0.9203	
Tables	Count	64	85	149
	Expected Count	90.1	58.9	149.0
	% within Subject	2.8%	5.6%	3.9%
	Adjusted Residual	-4.5	4.5	
	P value	0.00001	0.00001	
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	0.00001	0.00001	
Timelines	Count	6	23	29
	Expected Count	17.5	11.5	29.0
	% within Subject	0.3%	1.5%	0.8%
	Adjusted Residual	-4.4	4.4	
	P value	0.00001	0.00001	
Comic Strips	Count	5	18	23
	Expected Count	13.9	9.1	23.0
	% within Subject	0.2%	1.2%	0.6%
	Adjusted Residual	-3.8	3.8	
	P value	0.00015	0.00015	

Overall, there were a total of 350 instances of additional elements (i.e., hybrids, keys, or insets). Table 8 presents the frequency and percentages of those elements in the sample. Because some visuals contained multiple elements, this data was not orthogonal and it therefore did not meet the assumptions necessary for a chi-squared test (McHugh, 2013). However, I can see that science textbooks had a higher percentage of hybrid visuals and insets, while social studies textbooks contained a higher percentage of keys.

Table 8. Frequency and percentages of elements in textbooks

Elements	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%)

Functions of visuals

A majority of the visuals served a representational function. In other words, 60.9% of visuals in these textbooks accurately reflect information from the main text. This result seems logical as these visuals were, overall, 62.4% photographs and 16.3% images (see Table 9). A majority of those photographs and images simply presented the information described in the written text. By contrast, other types of visuals, such as tables and graphs, often add information not found in written text, which requires readers to make a connection. Additionally, there was no use of transformational visuals, and very little use of decorative visuals. As Levin and colleagues (1987) originally proposed these five categories 30 years ago, and the purpose of visuals in text may have shifted. The shift away from using visuals as simply decorative is positive, although the use of visuals for mnemonics may still hold promise for retaining complex material.

Table 9. Frequency and percentages of visual functions

Functions	Science	Social Studies	Both
Total	2324	1520	3844
Representational	1490 (64.1%)	850 (55.9%)	2340 (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%)

X^2 (3, N = 3844) = 69.864, $p < 0.001$, Cramer's V = .135. Note*:* As there were no transformational visuals, the degrees of freedom were reduced to 3.

The result of the chi-square test demonstrated a significant difference between science and social studies textbooks associated with functions, X^2 (3, N=3844) =69.864, $p < 0.001$, with a small effect size, Cramer's V = 0.135. I again adjusted the alpha levels for the post-hoc test, in this case dividing the standard 0.05 by eight to yield $p < 0.0063$. When examining each specific function, I found the proportion of representative visuals in science textbooks is significantly different from that in social studies textbooks (see Table 10). Moreover, the results of pairwise tests also demonstrated that the proportion of representational and organizational visuals significantly differ in social studies and science textbooks, $p < 0.0063$. Social studies textbooks contain a larger proportion of organizational visuals, and a small proportion of representational visuals, when compared to science textbooks. The proportions of interpretational visuals and decorative visuals in social studies textbooks were not significantly different from those in science textbooks.

Table 10. Visual functions Post-hoc analysis results

		Science	Social Studies	Total
Representational	Count	1490	850	2340
	Expected Count	1414.7	925.3	2340.0
	% within Subject	64.1%	55.9%	60.9%
	Adjusted Residual	5.1	-5.1	
	P value	0.000	0.000	
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	0.194	0.194	
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	0.000	0.000	
Decorative	Count	53	29	82
	Expected Count	49.6	32.4	82
	% within Subject	2.3%	1.9%	2.1%
	Adjusted Residual	0.8	-0.8	
	P value	0.424	0.424	

Finally, I analyzed connection visuals separately. In total, 1615 (42.01%) of the visuals contained new information. Among those visuals, 73.4% provided information clearly linked to the text, which is easy for students to interpret (see Table 11). The remainder (26.6%), were coded as Level 2, and provided new information not concretely linked to the text, which would be more difficult for students to interpret. No examples of Connection-3 were found, and thus no post-hoc analysis was necessary.

Table 11. Frequency and percentages of connection visuals

Connection	Science	Social Studies	Both
Total	775	840	1615
Level 1	611 (78.8%)	574 (68.3%)	1185 (73.4%)
Level 2	164 (21.2%)	266 (31.7%)	430 (26.6%)

X^2 *(1, N*=1615) =22.771, $p<0.001$, Cramer's V =0.119

The findings indicated that the proportions of Level 1 and Level 2 visuals in the science textbooks differed significantly from those in social studies textbooks, X^2 $(1, N = 1615) = 22.771$, $p < 0.001$, with a small effect size, 0.119. Referring to Table 12, social studies textbooks contained more level 2 visuals. By contrast, science textbooks had a higher proportion of Connection-1 visuals.

Table 12. Visual connections analysis results

		Science	Social Studies	Total
Level 1	Count	611	574	1185
	Expected Count	568.7	616.3	1185.0
	% 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%

Discussion

Before we can be strategic in preparing students to navigate the visual complexity of modern informational texts, we need to understand the evolving state of texts to know what students will encounter as they read. Additionally, as our understanding of disciplinary literacy extends, we need to consider the visual demands and conventions of graphics by disciplines. Therefore, this study aimed to investigate visual types and semantic functions present in current US 3rd and 5th grade science and social studies textbooks. In general, the results regarding the most common types and functions of visuals are consistent with the findings in Fingeret's (2012) previous study. Most notably across both studies, photographs and images (e.g., drawings, cartoons) are the most common visuals in textbooks. In addition, the majority of the visuals served a representation function in both studies.

In addition to these similarities, I revised coding and analysis strategies revealed some notable findings in relation to the types and functions of graphics in current science and social studies textbooks. In the following section, I first discuss the main findings as organized by research question. Next, I examine other differences between the two disciplines that were identified during analysis. Finally, I discuss the implications of this work and directions for future research.

Types and Semantic Functions of Visuals

To answer the first research question (*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?*) I examined to the visual frequencies. There was a high variety of visual types and sub-types within the textbooks. One example of the variety was the different types of photographs. Within photographs, I found examples of simple photographs, photo clusters (in which, there are some connections among multiple photos), photo hybrids (e.g. a photo with an image), and photographs with cut-aways. While a simple photograph may be typically accessible, a photo with a cut-away overlay is relatively complex. An example of such type of photograph would include a cut-away diagram to illustrate the heart, embedded in a photo of a child's body structure. While this visual provides much information (e.g., the location of the heart within the body and the anatomy of the heart), to comprehend this photograph students would need to discern and attend to different levels of representation.

Findings indicated that photographs and images are the most common visuals in these textbooks (62.4% and 16.3%, respectively). Additionally, most of the visuals (60.9%) served a representation function, which provides a concrete example to support the text. This is logical because a photograph often illustrates a single example of a broader category (e.g., a photograph of a rockslide to demonstrate erosion). Drawing upon Dual Coding Theory (Sadoski & Paivio, 2003; Clark & Paivio, 1991), linking abstract concepts to a concrete example can help students comprehend and recall a newly learned concept.

Beyond theoretical support, the use of photographs and other representational forms has empirical support. According to a recently conducted meta-analysis (Guo et al., 2017) complex visuals, especially pictorial and relational diagrams, only resulted in a small to medium positive effect (Hedge's g = 0.29) on students' reading comprehension, compared with pictures or photographs (Hedge's g = 0.64). This finding in favor of simple visuals may be related to issues of cognitive load. In other words, adding complex graphics to an already complex subject may result in cognitive overload. Therefore, simpler visuals may more beneficial.

However, this should not be interpreted to imply that representational visuals are simply redundant with this text – over 40% of the visuals coded added new information to the written text. Therefore, students should be encouraged to attend to visuals because they are providing additional information. Drawing upon Multimedia Learning Theory (Mayer, 2002) visuals are considered to be of higher quality when they both reinforce and extend the reader's knowledge, rather than only representing information in the text. Unfortunately based on previous work (e.g., McTigue and Flowers, 2011; Hannus & Hyona, 1999), students may not be fully attending to the graphics. Therefore, they run the risk of missing key information. This has implications for assessment as well, as many high-stakes science texts require students to interpret visual information. In a recent review of state science tests, 79.5% percent of test items could not be answered correctly without examining the graphics (McTigue, 2009). Clearly, students need both opportunity and instruction in interpreting visuals in informational texts.

On a positive note, the majority of visuals that added new information (73.4%) were coded at the lowest level of Connection. While future research is needed to describe the implication of this finding, it may indicate that the visual information would be relatively simple for the reader to integrate with the text. Younger readers have demonstrated difficulty perceiving the connections between information in two mediums (Jian, 2016), so this preponderance of Level 1 Connections is a positive finding for this age group. The remaining such visuals were coded at a Level 2 Connection, which indicates that the reader would need to make an inference about either how to interpret the visual or how to connect the visual with the textual information. I did not find any instances of Level 3 Connections visuals, which is a promising finding as it indicates that the visuals tended to be explicitly linked to their corresponding text.

Differences between Textbook Disciplines

Answering the second research question: *Do the types and semantic functions of visuals differ in science and social studies textbooks, if so, how do they differ*?, yielded some interesting patterns. On average, science textbooks contained more diagrams and photographs than social studies texts. These visuals frequently served a representational function. This finding is logical in that science often is describing abstract processes that are too small (e.g., microbiology) or too large (e.g., plate tectonics) to visualize easily. Therefore, visual representations can help readers link the abstract process to a concrete example. Additionally, scientists self-report that they seek different representations of an idea while reading (Shanahan & Shanahan, 2008). For example, when observing the reading of discipline specific texts, 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 graphics were essential to fully communicate a concept. Thus, this finding may indicate that science textbooks for children, in some manners, are adhering to disciplinary expectations.

By contrast, social studies textbooks were more likely to contain a variety of visual types, including graphs, timelines, maps, tables, and images. Considering the fact that social studies educators include those from "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 logical that there the visuals in this field should be similarly diverse. Additionally, social studies textbooks were more likely to contain organizational or interpretational visuals. These form and function findings are connected as tables and maps generally add to the organization of information. However, this variety of visuals presents challenges as different skills are needed for successful interpretation. For example, researchers have demonstrated specific skills are needed for students to navigate maps (Brugar & Roberts, 2014b); timelines (Brugar & Roberts, 2014a) and tables (Brugar & Roberts, 2015) in social studies texts. Furthermore, there are a variety of common misconceptions students have about these types of visuals. Roberts and Brugar (2013) conclude that critical reading of 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." (p. 162). Therefore, variety of visuals in social studies texts will likely challenge students' comprehension of texts.

Diversity within Science Textbooks

Although my purpose was to capture general trends in the use of visuals within modern textbooks, my interpretation also revealed qualitative differences across texts - in particular between the *Science Resources* and *Science Fusion* series. First, I found a wider variety of visual categories in *Science Fusion*. Additionally, the included visuals, particularly diagrams, tended to be more complex, as they included many hybrid visuals. These hybrid visuals included items such as cut-away diagrams embedded in a photo, or a timeline combined with photos. Therefore, it is must be acknowledged that while visuals are increasing in general in the instructional materials, different publishers are making unique decisions regarding their inclusion and complexity.

Moreover, in certain texts, such as *Science Fusion*, visuals required student interactions. For instance, while not a "workbook", this textbook asked students to complete tasks such as apply what they learned from the text and fill in blanks on a diagram. Such an interactive design has not been noted in earlier research, and is more typical of a supplemental, disposable workbook, than a textbook. Thus, *Science Fusions* contains more extensional and interpretative visuals, which may work to engage students so that they do not disregard the visuals. It is unclear, however, if such a design would be helpful for students because interaction with the textbook may be limited. Practically speaking, schools typically reuse textbooks across many years and therefore would not encourage students to write on the pages.

Implications and Directions for Future Research

These findings provided significant implications for future research in the field of visual literacy, as well as disciplinary literacy. The most immediate impact should be to influence the focus of visual literacy instruction in elementary school classrooms. Children need explicit instruction in all content areas regarding how to approach and comprehend images within texts. In addition, content-specific instruction (e.g., how to read diagrams in science texts or graphs and maps in social studies) is also required. Future research should investigate instructional strategies that will help children become effective readers of visuals in specific content areas. This work provides some guidance on the type of visuals that students may encounter most in their school reading.

Additionally, findings attempt to describe the complexity of individual visual displays in social studies and science textbooks. One implication for researchers may be to focus on providing students effective instructions on reading specifically complex visuals. For example, when a single visual includes a photograph with a cutaways, which reveals a diagram and a key, the companion instruction for such a visual must also be layered. Unfortunately, while the field has made progress to describe and quantify aspects of text complexity (e.g., Williamson, Fitzgerald, & Stenner, 2013), such analysis has not occurred for visuals.

Further research is also needed to fully understand the utility of captions. I identified captions as brief writing separate from the main text and visually connected to the image (e.g., in a shape near the picture). However, during the coding process, I found that some captions, especially those in the *Science Fusion* text, were very long and written below or embedded within visuals. These type of extended captions blur the line between adjunct visuals and the main text. Recent evidence suggests using eye-tracking technology demonstrated that when science texts contain illustrations with labels, students spent more time rereading the labels, inspecting the illustration, and integrating the two forms of information (Mason, Pluchino, & Tornatora, 2013). This indicates that reading a combination of texts and graphics requires additional cognitive energy. With these extended captions, students need to read back and forth among three sources: captions, visuals, and main text. Therefore, one concern raised here is whether or not captions may lead to cognitive overload, especially for young students or English Language Learners who have difficulties processing multi-modal texts. Thus, the field requires more efforts investigating the impact of captions and visuals on young students' reading comprehension.

Limitations

The goal of the present study was to collect a sample of textbooks to examine their visual content. I took steps to ensure the sample was purposeful and diverse, but it not a random sampling from school use. Furthermore, I chose textbooks included on state-wide adoption lists, but I do not know how many schools actually chose to invest in these texts for student use.

Additionally, while my coding scheme and procedures were based upon previous research, I required some modifications to better represent the visuals present in contemporary textbooks. I recorded these changes and engaged in extensive discussions to ensure reliability; however, future research will be required to fully validate this coding scheme.

Finally, I did not use e-books or quantify the type of visuals, particularly interactive visuals that students would encounter during online reading. As students are spending greater proportion of their time reading online, the impact of the medium with the graphics should be considered. For example, Mangen, Walgermo, and Bronnick (2013) found that students had better comprehension reading texts on paper rather than on computer screens. One of the explanations offered is directly relevant for graphics, as they noted 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 students encounter in computer-based informational texts.

Conclusion

The results of this study give researchers, teachers and publishers an overview of categories and functions of visuals in contemporary science and social studies textbooks. Overall, I found nine major types of visuals and 54 sub-types, 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 skill set but that discipline specific. Researchers must begin investigating strategies for classroom instruction that will support students’ ability to make meaning of visuals, thus supporting their overall comprehension and retention of informational texts.

CHAPTER III

CRITICAL ANALYSIS OF RESEARCH ON THE IMPACT OF VISUAL LITERACY FOR LEARNING: STRENGTHS, WEAKNESSES AND RECOMMENDATIONS FOR IMPROVEMENT

In a qualitative comparison of elementary texts twenty years ago, Walpole (1998) argued that the changing layouts and increasing complexity of graphics would compel teachers to modify how they present information and teach reading strategies. Since Walpole's analysis additional studies continue to provide evidence that visuals in literacy use is increasing at rapid pace (Fingeret, 2012). Consequently, students are frequently encountered hybrid, abstract, and complex visuals in classrooms, which required well-developed skills in graphical conventions to navigate these texts (McTigue, 2009).

To provide best visual literacy instruction for students, researchers have examined a plethora of related issues, including examinations of how students process graphics presented in texts (Hannus & Hyona, 1999; Norman, 2012) and the extent that graphics support students' reading comprehension (Carney & Levin, 2002; Cromley et al., 2013, Norman, Robert, & Cocco, 2015). Yet, relative to traditional literacies, as well as other new literacies, visual literacy receives limited attention in both research and teacher preparation. For instance, very few studies have explored teachers' knowledge of graphic conventions and instruction (Coleman, McTigue & Smolkin, 2011), as well as younger students' cognitive process and learning strategies when using graphics (Norman, 2012). As such, research in visual literacy has not kept pace and is relatively nascent in comparisons to research in other aspects of literacy.

Literature Review

Convergent findings from existing research tend to be contradictory. For instance, with working with college students, researchers have established multiple designing principles, demonstrating the manner that providing graphics can robustly benefit students' learning (Mayer & Sim, 1994; Mayer, 2002). However, for younger readers, simply providing graphics have proven at time to have no effect or even hinder their reading comprehension (Schrader, & Rapp, 2016, McTigue, 2009). Moreover, when researchers try to synthesize visual literacy findings, there are few clear patterns. According to a recent meta-analytic review (Guo, Zhang, Wright, McTigue, 2017), compared with college students, adolescent (grade 7-12) students show only modest improvement of reading comprehension from instructional graphics (Hedges' g = 0.56 vs. 0.23 respectively). Yet further adding to the complexity, elementary students' (grade 1-6) benefits were more similar to college students (Hedges' g = 0.50), indicating that there is not a simple developmental progression. When controlling for other factors (i.e., graphic type, assessment format, study design, cognition demand) in the meta-regression model, these three groups did not yield statistically significant difference. Therefore, the answers regarding "when a graphic is worth thousand words" still remained unclear.

One possible reason for the lack of clarity in the research base (in addition to the relatively few number of studies) may be in the quality of the research which may lead to unreliable findings and potentially contradictory findings. For instance, Guo and colleagues found that assessment format significant moderated the effects of visual graphics. Specifically, when compared to most other types of assessment (open ended, mixed), graphics provided the least benefit for true/false (T/F) outcome measures. This moderation effect is not likely due to the cognitive challenge of true/false questions (which was controlled for by a different moderator) but because such assessment format only contains two alternatives (i.e., true or false) in each question, which can result in unreliable measures (Crocker & Algina, 2006). In other words, even students with no content knowledge can guess with 50% accuracy on each T/F item. Additionally, it is important to note that Guo and colleagues (2017) situated their study within 30-year research context, whereas some studies are dated. Thus, lacking reliabilities may potentially results in confusing findings on effects of graphics.

However, in previous decades, less attention was given to instrument reliability as well as other factors that contribute to research rigor (e.g., theoretical foundation, study validity) when exploring multimodal effect. When synthesizing previous research, past reviews that were published prior to 2002, primarily documented learners' characteristics and graphic design principles (Vekiri, 2002; Carney & Levin, 2002), which provide little insight regarding study design and instruments. Although a recent meta-analysis (Guo et al., 2017) explored these effects via moderator analysis of these factors, but this approach only allows researchers to quantify the effects of visual graphics. As such, qualitative and mixed method studies were excluded from analysis. In summary, current reviews have focused on the "*when", "why"* and "*for whom*" graphics are effective. However, before this research line can be more fully inquired, we need to consider the quality of such research on which we are basing our knowledge. Such a methodological review will help us understand the strengths and the weaknesses in the current body of visual literacy research and make practical recommendations for moving the level of the research forward.

Therefore, the current study detailed a critical proportion of a comprehensive systematic literature review by formally evaluating the quality of empirical research associated with the impact of visual graphics on students' learning in the K-12 context. In this study, I first depicted the screening and coding process, and then I described findings and addressed my concerns regarding the methodological issues in the field of visual literacy. Last, I proposed recommendation and future direction for researchers and practitioners.

Method

To locate relevant studies published in peer-reviewed journals dated between January 2002 and October 2017, I implemented an initial search in three databases (PsycInfo; Eric; Education Source), using the keywords "*picture,*" "*image,*" "*visual,*" "*graphic,*" "*timeline,*" "*table,*" "*photograph,*" *diagram,*" combined with the term "*learning*". Figure 2 presents detailed information regarding searching and screening process. To locate all eligible studies, I then conducted an ancestral search and added 16 articles for full screening. In total, I screened 1677 articles at the abstract-level, and 189 articles at the full-text level.

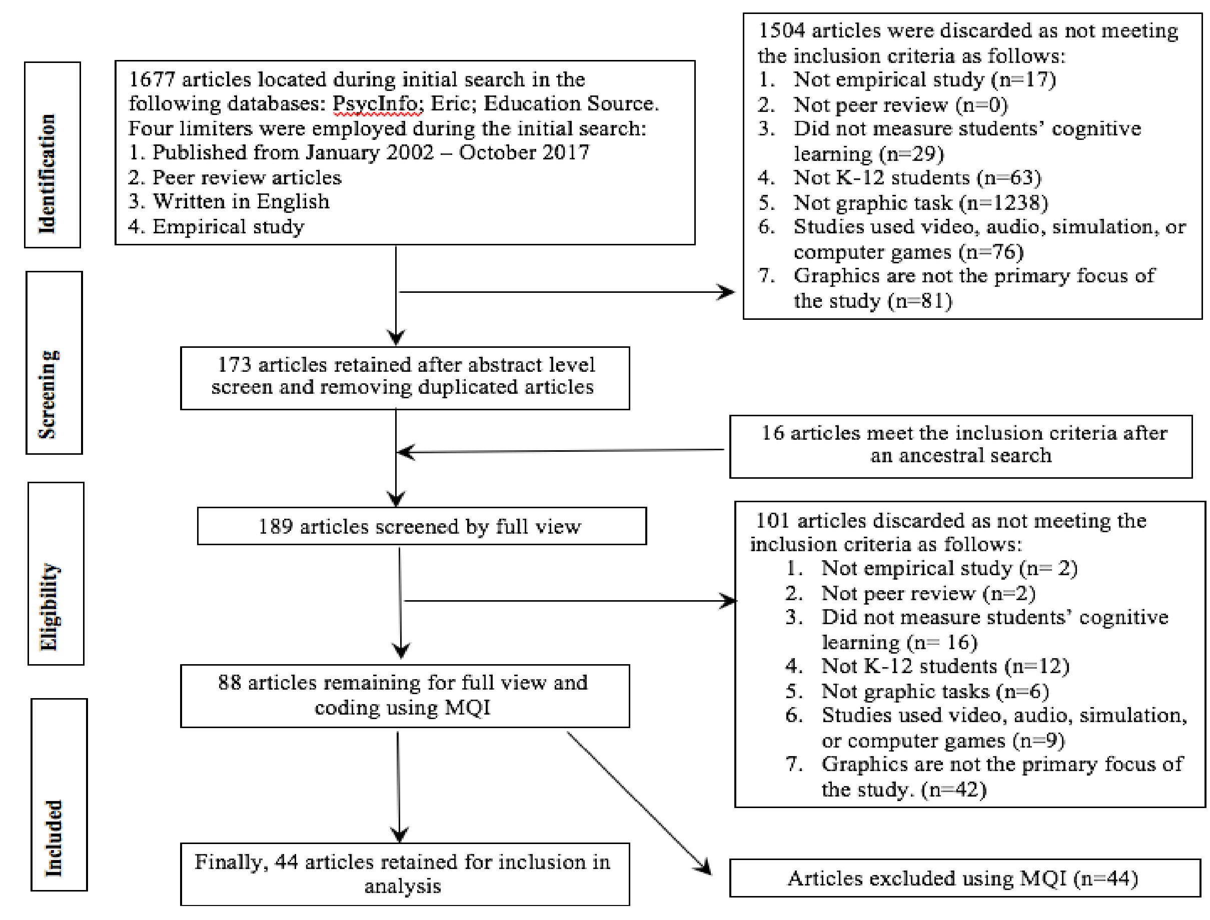

Figure 2. Article retrieval and identification process

Included studies met the criteria as follows: (a) empirical studies, (b) published in a peer-review journal, (c) measured students' cognitive learning as an outcome, (d) included participants enroll in K-12 education, (e) involved graphic tasks, (f) static graphics were the primary focus of the study. For example, studies that used videos, audio narrations, simulations, and computer games were excluded. Studies quantifying or describing students' ability to learn graphics were also eliminated, because they did not meet my research purpose. This process resulted a total of 88 articles that were coded using the methodological quality indicators.

Quality Indicators

These 88 articles were coded using methodological quality indicators, which have been employed in other areas of literacy (see Risko et al., 2008; Miller, Scott, & McTigue, 2016). The original coding scheme performed well for evaluating the quantitative visual literacy studies, however, it proved less adequate for evaluating select qualitative, and mixed method research. For example, the original coding scheme provides language appropriate for capturing both quantitative validity and reliability but offers much less specificity for capturing analogous concepts in qualitative research. Additionally, previous coding procedures did not address how to score mixed method studies. Thereby, I modified the methodological quality indicators (MQIs) to capture the larger range of research quality endemic to this corpus. For example, as evidenced in Figure 3, as qualitative studies were evaluated from four aspects, the extent that: (a) researchers used multiple sources of information to synthesize findings; (b) more than one investigator was involved in data collection and analyses; (c) researchers represented participants' viewpoints; (d) researchers reported sampling method (e.g., purposive sampling, typical cases). Moreover, I also added a new indicator, to describe the limitation and future direction of the study (See Figure 3).

Standard	Quality Criteria	Scale
Standard 1: Provides a clear argument that links theory and research and demonstrates a coherent chain of reasoning. Explicates theoretical and previous research in a way that builds the formulation of the question(s).	1.1 Explicates theory and/or previous research in a way that builds the formulation of the question/purpose/objective that that can be investigated empirically. 1.2 Explicitly links findings to previous theory and research or argument for study.	1 - Meet all criteria 0 - Meet 1 or less
Standard 2: Applies rigorous, systematic, and objective methodology to obtain reliable and valid knowledge relevant to education activities. (Ensures that methods are presented in sufficient detail and clarity to clearly visualize procedures)	2.1 Data collection should be described so that readers can replicate the procedures in a quantitative study or follow the trail of data analysis in a qualitative study. For a quantitative study, a researcher should report some of the following: a) Were participants described, and was the sample well characterized? *(Description should include age/grade language and, preferably, the type of graphics, and measurement used in the analysis.)* b) Duration of intervention (if applicable) c) The materials used in the study *(a sample of graphic or text if applicable)* For a qualitative study, researcher should report some of the following: a) Were participants described, and was the sample well characterized? *(Description should include age/grade language and, preferably, the type of graphics, and measurement used in the analysis.)* b) The number of observations, interviews, or documents analyzed. c) If interviews and observations are taped and/or transcribed. d) The duration of the interviews or observations.	2 - Meet all listed criteria 1 - Meet some or most of the criteria 0 - Meet 1 or less

Figure 3. Methodological Quality Indicators (Reprinted from Risko, et al., 2008, Scott et al., 2013; see also)

<table>
<tr><th>Standard</th><th>Quality Criteria</th><th>Scale</th></tr>
<tr><td>Standard 2 (Continued)</td><td>2.2 Was evidence of reliability and validity provided for data collected?

For a quantitative study, a researcher should report some of the following:
a) Used a published assessment or used a researcher developed instrument with a documented pilot study.
b) Reports reliability of the sample (e.g., describe coefficients, test-retest, Cronbach's alpha)
c) Report information about instrument development and adaptations for specialized population.
d) Instrumentation-does it measure what it is designed to measure and accurately performs the function?

For qualitative studies were trustworthiness, credibility, and/or dependability addressed and reported?
a) Were multiple sources of information used to corroborate findings?
b) Was more than one investigator involved in collecting and analyzing data?
c) Were researchers checking to represent participants' viewpoints?
d) What kind of sampling occurred (e.g., purposive sampling, unusual cases, typical cases).</td><td>2 - Meet all listed criteria

1 - Meet some or most of the criteria

0 - Meet 1 or less</td></tr>
<tr><td rowspan="2">Standard 3: Present finding and make claims that are appropriate to and supported by the methods that have been employed.</td><td>3.1 Findings and conclusions are legitimate or consistent for data collected.</td><td>1 - Meet all criteria

0 - Meet 1 or less</td></tr>
<tr><td>3.2 Implication and limitation.
a) Provide implication for researchers or practitioners.
b) Explicates limitations.</td><td>1 - Meet all criteria

0 - Meet 1 or less</td></tr>
</table>

Figure 3. Continued

Regarding mixed-method research, I coded the qualitative and quantitative methods independently, and then averaged the final score, which allowed me to emphasize both methodological elements.

Similar to the scoring procedures in previous research (Risko et al., 2008; Miller, Scott, & McTigue, 2016), we scored each study using the following criteria: 1 points for a study that meets 0 to 3 quality indicators, 2 points for a study that meets 4 to 6 quality indicators, 3 points for study which meets 7 to 8 indicators. Only when a study received a score of 3, it can be included for final analysis. This step eliminated 50% of the articles (n=44).

Inter-rater Reliability

To establish coding reliability, I also invited another researcher to code 4 studies using the MQIs. Then we discussed discrepancies and any other issues identified during the coding process. Moreover, we met regularly to consult with other team members to modify these indicators and procedures until the final coding protocol was established. Once all modifications were made, two new articles were coded with an inter-rater reliability of 100%. Then I coded all samples and the second rater randomly selected 25% of the entire sample (n=23) for double coding. The agreement on the overall score was 94.6% (174 of the 184 items reflected agreement). The inter-rater reliabilities on standard one, two and three of the MQIs was 100%, 90.22% and 97.8%, respectively (dividing the number of agreement items by the total items, then multiplying 100 percent).

Results

Overall, the analysis demonstrated that quantitative methodologies are more prevalent in visual literacy research with a proportion of 69.32%, when compared with qualitative research method (n=23.86%). I found few studies (n=6) employing mixed method to examine how visual graphics affect students' learning, which is surprising because mixed methods allow researchers to capture aspects of both processes and outcome. In the following sections, I present the strength and weakness regarding the methodological qualities of the 88 studies.

Methodological Strength

I found that almost the entire sample (87/88) met the first MQI standard, requiring studies to "explicate theory and/or previous research in a way that builds the formulation of the question that can be investigated empirically" (see Figure 3). Moreover, the majority of studies explicitly linked findings to previous theoretical perspectives or research (n=83). Together these findings indicate that visual literacy researchers build a strong connection between previous research and the formation of their current research questions. Regarding study design, all studies adequately provided examples of materials used, such as a selection of diagram or a piece of students' constructed concept map. Such transparency of materials also allows researchers to better build upon the work of others.

Methodological weakness

The MQIs coding scheme allowed me to evaluate qualitative and quantitative aspects regarding the dimension of data collection and study reliability and validity (see standard two in Figure 3) and uncovered three prevalent weaknesses of design: lacking details regarding (a) data collection, (b) study reliability and validity, and (c) limitation and implication.

The first concern regards to data collection. Specifically, 66.67% of the qualitative studies only received partial credits on standard 2.1. They either did not provide a clear description of study procedure or illustrated students' characteristics. For instance, information regarding details of interviews (e.g., duration) and whether data was collected from special populations (e.g., low-achieving students) was frequently not reported. In terms of quantitative research, 26.3% of the studies did not fully meet standard 2.1, also due to providing limited information of the procedure of data collection. For instance, several studies documented that researchers provided instruction to students to facilitate their learning with graphics, however no details about the intervention were reported, thus not allowing for replication.

The second concern regards to study reliability and validity, was that over two thirds of the qualitative studies did not meet all criteria in standard 2.2 (n=76.19%). Few qualitative studies clarified why a particular group of students was selected (e.g., purposive sampling). Without such information, I am unable to confirm whether the data would support valid research findings. For quantitative research, over half of the included studies received partial credits on the analogous standard 2.2 (n=54.1%), which may lead to untrustworthy results. For example, select studies employed researcher-designed assessments without reporting any information regarding the development of the assessment (e.g., pilot studies, removal of unreliable items). Among studies that used published assessments, several researchers did not report reliability statistics from the actual sample, yet the test was adapted for a particular group of participants.

For mixed method studies, as mentioned above, I coded both the qualitative and quantitative piece respectively, and then calculate average scores. Four of the six studies received partial credits because they provided limited description of qualitative data procedure. For instance, in one study, researchers first conducted an intervention and assessed students' learning. To supplement the quantitative analysis, they also collected qualitative data via interviewing 6 students who show the least improvement. However, researchers the researcher did not provide the interview questions, duration of the interview, nor how the data was coded. Only a summary of students' responses was provided, which provides little evidence of credibility and trustworthiness.

Furthermore, AERA (2006) highlighted that scientific studies should state their scope and limits of the inquiry and should align these with the perspective, aims, and conceptualization of the inquiry, as such information are very essential for future research (AERA, 2006). Unfortunately, based on my analysis, I found over 55% studies did not explicate limitation or implication for researchers or practitioners, which raised my third concern. Especially, in many cases, researchers often neglected to present limitations regarding study design, participant selection, implementation fidelity, and data analyses. For instance, some researchers randomly selected a group of students and assumed that participants would not have background knowledge of a specific topic but without formal documentation. The same researchers would tend to might explicitly record the data collection process, adaption of instruments, and intervention effects, and thoughtfully interpret their findings. However, less attention was given to the nuances of participant selection, although such information is very critical for future research.

Limitations

This study has several limitations. First, including only articles published in English, may have resulted in a biased sample. For instance, 59.1% of the included studies recruited participants from United States (n=26) and the remaining represented research from eight countries (n=18). These percentages may reflect a potential inclusion bias. Additionally, although I believe dissertation studies and conference papers may also made significant contribution to the field of visual literacy, to ensure the rigorous review process and the high quality of included samples, I only searched peer-reviewed articles. Third, this review is limited to research concentrating on the impact of visual graphics on students' learning. Thus, studies focusing on understanding students' ability to use and interpret graphics were eliminated.

The last limitation is regarding the methodological quality indicators. Although I adapted the previous coding scheme to this research, at more granular level, I am unable to record the extent that a study met the criteria. The tool operates as a screening tool, rather than a descriptive tool. This limitation was particularly meaningful for the first and third dimensions. For instance, the MQI 3.2 clearly mentioned that studies should explicate limitations. However, when implementing the MQIs, I found some researchers only briefly described limitations in few words whereas others provided great details. Although both groups of studies met the criteria, the richness of description is not captured.

Recommendations and Future Directions

As proposed by AERA (2009), rigorous studies should be credible, persuasive and transparent. Although convergent systematic reviews were conducted in the field of visual literacy, aiming to answer the question *"when", "how", "why*", and *"for whom*", graphics are most effective, reviews focusing on examining the methodological quality of current research are very limited. Thereby, this analysis serves as a springboard to emphasize the importance of study quality, and also aimed to provide recommendations and directions for future endeavors in the relatively nascent field of visual literacy. As a supplement to the statistical descriptions, in the following section, I will summarize few studies that achieve high levels of rigor and can provide exemplars for future research.

Building from the Strength of Previous Research

Although 44 studies that met the MQIs requirement, several of the studies demonstrative notable levels of quality. In summary, four distinctive research practices emerged: (a) provided details regarding students' characteristics; (b) collected data from multiple sources; (c) explicitly stated the development of instrument and the reliability and validity; (d) used mixed-methods in a planful and thoughtful manner.

Providing details regarding students' characteristics. Although it is very essential to examine student-level variables, according to a recent meta-analysis (Guo, Zhang, Wright, McTigue, under review), such information was often lacking. However, in this review, many studies explicitly depicted students' characteristic (e.g., reading skills, language status), or grouped students based on their academic ability (e.g., low-achieving students and high-achieving students). For instance, DiCecco and Gleason (2002) examined the effects of graphic organizers on middle school students with learning disabilities (LD). They delineated a series of criteria to characterize their sample. Specifically, the LD students were selected based on the 1986 Oregon State administrative rules, and they enrolled in special education programs. Additionally, to ensure the group equivalence, they also measured students' reading skills on a normed and standardized assessment. Such information is particularly important as basic reading skills may potentially moderate students' overall learning when studying graphics (Norman, Roberts, & Coco, 2015). Moreover, DiCecco and Gleason (2002) also considered students' prior knowledge as part of their study design. Unlike typical studies, which have student self-rate their knowledge, students in this study completed a 20-item multiple-choice assessment (reliability coefficient = 0.76). Through the rigorous study design, DiCecco and Gleason (2002) were more capable of controlling for student-level variables, and to fulfill the goal of examining the true effects of graphical intervention. Thus, my first recommendation is that future researchers should analyze and report details regarding relevant participant characteristics.

Collecting data from multiple sources. Several qualitative studies (e.g., Åberg-Bengtsson, 2006; Arya & Feathers, 2012; Muthersbaugh, Kern and Charvoz 2014) enriched the result by collecting data from multiple sources such as students' and teachers' interviews, researchers' field notes, and classroom observation. For example, in one case study worked, Muthersbaugh, Kern and Charvoz (2014) collected data from three sources. They qualitative analyzed students' responses from interviews, artifacts, and writing journals to evaluate how graphics affect students' understanding of environmental science. To provide more nuanced interpretation of students' achievement, they also incorporated data from teachers' interview (on instructional practice and students' performance), and researchers' journals. As such, the study presented valid and valuable perspectives through synthesizing data from multiple sources.

Moreover, convergent studies collected data via eye-tracking and integrated it with those collected from traditional outcome measurements, aiming to fully explain students' reading processes (e.g., Jian, 2017; Mason, Tornatora & Pluchino, 2013; Arya and Feathers, 2012). For instance, Arya and Feathers (2012) collected data through the method of eye-tracking, oral reading and retelling performance. They measured the numbers and durations of students' eye-fixation on text and visuals, as well as analyzed students' oral reading and retelling performance. Data from three sources was integrated and analyzed to better capture the complexity of students' reading processes as they transacted with texts. Specifically, the eye-tracking data shows that when students encountered unfamiliar vocabularies, they fixed on the word for many times (e.g., students had more than 20 times fixation on each problematic word). Interestingly, when integrating this finding with oral reading data, researchers found that the students used multiple processing strategies to decode the word, such as using the strategy of place-holding a text word by substituting another word. Additionally, they also use illustration clues to identifying words and construct meaning. Therefore, the repeated fixations represented deep processing.

Explicitly describing the development of instruments. Based on Mayer's study (2001), graphics may benefit students' higher-order learning skills, such as problem-solving transfer, but not verbal recall. However, limited studies reported details of such types of comprehension. Thus, I recommended that future research considers assessment complexity, and explicitly describe the procedure of how they develop instruments for their research purpose. Fortunately, I found several studies, which provide models for this recommendation. For instance, Cromley and colleagues (2013) used a multiple-choice measure to test four dimensions of learning (i.e., conventions of diagrams, interrelating of text and graphics, integrating the new information with prior knowledge, recall of details of a diagram). They also conducted exploratory factor analysis on students' performance to identify subscales of reading comprehension measures (i.e., literal comprehension or inferential comprehension). This enabled researchers to determine whether graphics could facilitate students' different levels of learning as well as provided evidence of test validity.

Use of planful mixed-method. Among those 6 mixed method studies, two studies were conducted with particularly high-level of rigor (i.e., Norman 2012; Kwon & Cifuentes, 2009). For example, Norman (2012) conducted research in two waves. First, qualitative data was collected through a think-aloud protocol to depict students' thinking process when studying graphics. Through establishing a thoughtful coding scheme, Norman counted the frequency of each think process and measured students' learning outcome through retelling and comprehension questions. Finally, a multiple regression analysis was conducted to test the correlation between graphical comprehension and overall comprehension. These mixed methods would allow researchers not only to understand the learning outcome, but also reveal the underlying threats that students may encounters during reading, which provide valuable information for future reading intervention.

Learning from the Weaknesses of Previous Research

Directly connected to the limitation of reports of instrument reliability and study validity, findings reflected a weakness of instrumentation across studies. As mentioned above, the major concern is that many studies implement researcher-designed instruments without evidence of validity and reliability. Thus, researchers should consider this aspect to ensure the reliability of research. Additionally, to reduce the reliance on researcher-designed measurements, other validated assessment should be developed, such as teachers' interview and surveys.

Furthermore, by examining the 88 studies, I found the ELL population was underrepresented. Surprisingly, only one study explored the effects of graphics on learning, with an ELL population, although in the reality, teachers are often encouraged to use graphical interventions to improve student's learning. This finding is consistent with a previous study, in which Guo and colleagues conducted a meta-analysis of 33 studies, among which, only 3 studies concentrate on ELLs.

Finally, among the 88 studies, we only identified 6 mixed-method studies. I recommend future endeavors to consider mixed methodology. For instance, besides collecting data from standardized measures, researchers could collect data from multiple sources, such as classroom observation, teachers' survey, researcher's field notes, students' artifacts. It allows researchers nuancedly interpret students' learning, not only based on students' test scores.

Conclusion

First, and pragmatically, this study updated a previously used methodological quality screening tools to make it more applicable for a wider range of literacy research and reflect the plurality of the field. Second, by employing the MQIs, my study critiqued the methodology quality of current research regarding the effect of visual graphics on students' learning, identifying trends in rigor and in limitations. To enhance future research, I present models of research with high-level rigors and identify multiple critical factors to improve research in visual literacy.

CHAPTER IV

RESEARCH ON THE IMPACT OF VISUAL LITERACY FOR LEARNING ACROSS THE DISCIPLINES: A SYSTEMATIC REVIEW

Visual graphics, in traditional and multimedia formats, are frequently used for content-area learning in the K-12 context. Moreover, in recent years, they have become increasingly complex, including hybrid, non-linear representations with various functions. As such, students often need support (e.g., scaffolding, explicit instruction, modeling) to integrate visuals with text and acquire content knowledge. However, relative to traditional literacies, as well as other new literacies, visual literacy still receives limited attention in research, particular regarding instructional strategies. Thus, current study aims to better understand the body of research on the impact of visual literacy for K-12 students' learning across disciplines.

Conceptualizing the Review

Rationale and Importance of this Review

Although there is increasing evidence indicating that the addition of visual graphics will contribute to students' learning (Mayer, 2001; Norman, 2012; Norman, & Roberts, 2015), findings in the field are sometimes contradictory. The research does not yet provide clear guidance of how to best illustrate complex topics across disciplines. Specifically, selected studies have documented the trend that adding graphics in the informational text results in new challenges for children. Specifically, to fully access the content, students need to apply multiple literacy skills to read, select, and integrate and produce information in text and graphics, which leads to the cognitive overload during the reading process (McTigue & Flowers, 2011; Duke, et al., 2013).

The increasing graphical complexity may be one reason that accounts for these challenges – visuals are rarely presented singularly within a page of linear text. Particularly, the typical layout of informational texts has undergone recent changes, influenced by the advent of more online reading and digital texts. Even traditional textbooks are less likely to be formatted in a linear arrangement. As such, the majority of informational text that current students encounter are multimodal in nature (Fingeret, 2012). In my analysis of third-grade science textbooks, for instance, revealed that the texts were richly multimodal. Texts typically contained information both in verbal and visual forms. For example, a paragraph on trees will have, not one, but a series of corresponding images, each illustrating different types of leaf.

Although some researchers have established graphical design principles, this work (e.g., Mayer, 2002) has primarily drawn upon research with the skilled adult readers (i.e., college students). Therefore, graphical design principles are less clear for younger students. Consequently, there is limited research-based for teachers in either the selection of appropriate visual materials and in strategies to improve younger students' content area learning from visuals. Thus, visual literacy classroom practices are frequently uniformed from research findings in K-12 classrooms. This disconnect is not the fault of teachers, but simply reflects an incomplete research base.

Yet teachers are responsible for such instruction. For example, Common Core State Standard address the needs for teachers to deliver visual literacy instruction for the goal of facilitating students' content area learning. For instance, when teaching young readers, (e.g., 4^{th} grade students), teachers should provide support to facilitate students' abilities to "interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears." In summary, there is an increasing call for researchers to examine effective visual literacy, however, before these research lines can be inquired, we should first understand "when" and "how" graphics are effective for elementary and secondary readers. Specifically, in what ways, the incorporation of visual graphic task could benefit K-12 students' content area learning.

Construct of Literacy and Learning

Robinson (1984) defined visual literacy as "the ability to communicate, understand, and produce communication visually". Similar to this definition, visual literacy also refers to "the ability to read, interpret and understand information presented in pictorial or graphic image" (Wileman, 1993, p.114). Synthesizing these definitions and others (Robinson,1984; Wileman, 1993; Metros, 2008), I defined visual literacy as the ability to read, interpret and produce visual information. Moreover, students should be able to ethically evaluate the accuracy and validity of visual information (i.e., Is that likely a real image or a product of photoshop? Is the caption accurate for what I am viewing? How do I ascertain this knowledge?). Unfortunately, there is limited evidence that visual literacy instruction occurs frequently in classrooms or that students have fully acquired such skills before being expected to independently make sense of visually-dense informational texts (Burgert & Robert, 2017). Therefore, we must consider how to integrate visual literacy with current curricula to improve students' learning across disciplines. Borrowed from Vacca and Vacca (2005), I defined *content area literacy* as skills, which allow students to learn content-area information. Although secondary students have dominated the discussion regarding *content area literacy*, researchers have raised attention on younger students' use of informational text for content literacy development. Particularly, in recent years, an increasing number of studies demonstrated that students could "reading to learn" while "learning to read" in early grades (Pearson & Billman, 2016), which call for research on younger reader's content area learning. Thus, my study aimed to investigate the impact of visual literacy on students' content area learning with a broader scope – focusing on K-12 students rather than secondary students.

Furthermore, according to Shanahan & Shanahan (2008), content area literacy represents a set of skills which support *disciplinary literacy*. It refers to literacy skills that "specialized to history, science, mathematics, literature, or other subject matter" (p.44). Compared with basic (e.g., decoding, high-frequency words) and intermediate literacy (e.g., common word meanings, and basic fluency), disciplinary literacy are more advanced and specialized literacy allows students to use different strategies to acquire information from various disciplines. It is important to note that with one-size-fits-all reading strategies, students can hardly complete the tasks in different disciplines. The visual literacy skills of ethically judging the accuracy, validity and the worth of visual information.

Moreover, despite the fact that the role of visual literacy in learning has been the focus of previous reviews (e.g., Vekiri, 2002; Carney and Levin, 2002; Renkl and Scheiter), limited studies have explicitly distinguished levels of learning outcome. For the goal of clarity, I operationalize learning outcomes through a brief historical perspective. Bloom and colleagues (1956) further specified the definition by classify cognitive *learning outcome* into six categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. More recently, Anderson and colleagues (2000) modified the Bloom's taxonomy, and proposed a new classification of cognitive learning, which reflects a more active form of thinking: *remembering, understanding, applying, analyzing, evaluating, and creating*. Situated within the K-12 education context, this review focused on the impact of visual graphics on cognitive domain of learning across disciplines.

Context of Previous Reviews

In the past decades, the focus of research reviews has shifted from the exploration of nature of graphics, to investigations of students' characteristics, to instructions regarding to visual literacy skills students need to acquire (Peeck, 1993; Carney & Levin, 2002; Vekiri, 2002; Renkl & Scheiter, 2016). These reviews (Vekiri, 2002; Carney and Levin, 2002; Renkl & Scheiter, 2016; Guo et al., under review) informed current study. In the following section, I present key findings from each review and then position the need for this review within the previous studies.

Vekiri's (2002) qualitative review of research examined the roles of graphics in learning from three theoretical perspectives: *dual coding theory* (Clark & Paivio, 1991), *visual argument theory (*Walter, 1981), and *conjoint retention theory ((*Kulhavey et al., 1993a, 1994*).* Under these theoretical frameworks, Vekiri synthesized relevant research and concluded that the effects of visual graphics were influenced by display characteristics (e.g. types, function, and complexity) and learners' characteristics (e.g. content knowledge, prior knowledge, and visual spatial ability). Findings further indicated graphics are beneficial only it allows learners to integrate information with appropriate cognitive loads.

Unlike Vekiri (2002), Carney and Levin (2002) quantified the visual facilitation in terms of functions (i.e., decorative, representative, interpretational, organizational, and transformative) that pictures serve in text processing. They identified transformational graphics (define trnsfmational here) as the most meaningful and interactive visuals, because, to the largest degree, it improved students' recall of text information. Other illustrations, such as representational, organizational, and interpretational pictures, had a medium to large positive effects on students' text-learning (*Hedges' g*=0.5, 0.7, 0.75 respectively). However, this research mainly concentrated on graphic characteristics, providing little insight regarding and potential effect of learner differences and the potential of classroom interventions.

Renkl and Scheiter (2017) attempted to address the research gap by distinguishing between material-oriented interventions (i.e., form) and learner-oriented interventions (i.e., function). In material-oriented intervention, researchers evaluated the effectiveness of visual designs by managing the complexity of visual and examined whether graphics supported integration across multiple representations. For learner-oriented interventions, the findings reported three types of intervention: training, pre-training and promoting, among which, only the training interventions were consistently successful, such as training spatial skills, convention-of-diagram training, and inference training. Regarding pre-training interventions, although they are powerful to enhance students' learning, these interventions were not specific to visual graphics and the learning process of graphics. In terms of promoting interventions, the effects were mixed. Prompts are helpful only when they are in form of implementation intentions – relatively easy to follow and do not require high cognitive demand.

More recently, in a meta-analysis, Guo, et al. (2017) evaluated the impact of visuals on reading comprehension, and potential moderator effects of learner and task variables. Findings revealed that the inclusion of graphics had a moderate overall positive effect (0.45) on students' reading comprehension, regardless of grade level, assessment complexity and study quality. When compared to mixed graphical presentations (e.g, different types of diagrams and pictures), pictures were more beneficial, indicating an advantage of realism in visual displays.

Although these four reviews are unique in content, they framed a need for the current study. Specifically, Vekiri's (2002) and Carney and Levin's (2002) studies were published a decade ago, which naturally limited their research scope, as they mainly focus on traditional representations and provide little information regarding multimedia format visuals. Moreover, both of the reviews attempted to establish graphic design principles with a focus on researcher-designed graphics. However, with the increasing complex graphics presented in modern textbooks, there is a call for investigating authentic materials that students encountered in classrooms.

Furthermore, Renkl and Scheiter's findings indicate greater promise for learner-oriented interventions rather than material oriented ones, which is beyond the scope of the previous reviews. Additionally, although Renkl and Scheiter (2015)'s informed our understanding of evaluating classroom interventions, they did not systematically consider factors such as students' grade level, testing language, and learning outcomes, which potentially moderate the effectiveness of graphics, according to numerous empirical studies (e.g., McTigue, 2009; Robert, Norman, Cocco, 2015). Although recent review (Guo et al., under review) made progress in answering *"why", "when"* and *"for whom"* of picture facilitation, due to the specific procedure of meta-analysis (e.g. only studies that measured sufficient quantitative information can be included for effect size calculation), the study provides little insight about research using think-alouds, eyes-tracking methods. Moreover, in summary, the aforementioned reviews discussed the impact of visual Therefore, this study aimed to extend the focus of previous reviews by employing the more comprehensive methodology of systematical review, which allowed me to include multiple types of empirical studies and generate themes through qualitative analyses. Specifically, this study is guided by the following questions:

1. What are predominant themes in the research on the impact of visual literacy for learning across the disciplines?

2. In what ways does the incorporation of visual graphic tasks benefit K-12 students' content area learning?

Method

A methodological approach of systematic literature review (e.g., Risko, et al., 2008; Miller et al., 2016) was applied to evaluate the qualities of those studies and synthesize the findings of empirical research associated with the impact of visual literacy on K-12 students' learning across disciplines. In summary, I applied a four-step process: (a) identifying and searching articles with a combination of multiple key terms in database, (b) screening studies using a set of pre-determined selection criteria, (c) coding studies and evaluating methodological quality of research based on *priori* quality indicators, (d) qualitative analyses of the included studies (e.g., Risko, et al., 2008; Miller, et al., 2016). As previously mentioned, rather than quantifying effect sizes from quantitative studies, this methodological approach allowed me to incorporate findings from multiple types of empirical research (e.g., qualitative, qualitative and mixed method). Additionally, through a systematic evaluation of methodological quality of studies, I only included research with rigorous study design. The following sections presented detailed procedures.

Literature Search

The study concentrated on the empirical articles that published between January 2002 and October 2017, because studies that published before were included in the previous systematic review (Vekiri, 2002; Carney and Levin's 2002), therefore, is not a focus in this review. Relevant articles were identified through searching in the following database: ERIC (ProQuest), PsycINFO and Education source, using a combination of a set of terms: *visual graphics (including pictures, diagram, image, table, timeline, photograph, flowchart, map, visual display,* *adjunct display), K-12 students (e.g., elementary and secondary students, K-12 students),* and *learning*. The intent of this search is to locate all eligible studies for further analysis, which yields a total of 1677 articles. Moreover, to extend the search parameters, I also conducted an ancestral search by examining the reference lists of previous reviews (e.g., Renkl and Scheiter, 2016). In total, I identified 1683 articles in this step.

Selection Criteria

The screening and coding process involved two steps: abstract-level screening and full screening. First, all 1683 articles were screened at the title and abstract level, using the following selection criteria: (a) written in English; (b) published between January 2002 and October 2017; (c) examined empirically; (d) published in a peer reviewed journal; (e) address a visual literacy across disciplines; (f) measured students' cognitive learning; (g) conducted in K-12 education context. After the abstract-level screening, I identified 189 articles that met the selection criteria, therefore, were included for full screening. After removing irrelevant articles and research that solely concentrated on computer games, video intervention, computer simulation, 88 articles remained in the database.

Methodological Quality Evaluation

To better fulfil my research purpose and evaluate the methodological quality of multiple types of empirical studies, I modify the guidelines established by Risko and colleagues (2008). The updated screening tool included six methodological quality indicators (MQIs) addressed three dimensions of studies: (a) theoretical alignment; (b) the clarity, reliability, and validity of research; (c) the consistency and appropriateness of the study's finding, and study limitation, and implication. Furthermore, the six MQIs correspond to a range of scores from 1 to 8. Specifically, the included studies were rated and scored using the following scale and criteria: high quality studies are those scored 8-7; moderate quality studies are those scored 6-4, low quality studies are those scored 3-1. I only included high quality studies for further analyses. The template in Figure 3 illustrated the seven quality indicators.

To establish the interrater-reliability, the second author randomly selected 26% of the entire sample (n=23) for double coding. The inter-rater reliabilities on MQIs standard 1, 2, and 3 are 100%, 90.22% and 97.8%, respectively, and the overall inter-rater reliability is 94.6% (dividing the number of agreement items by the total items, then multiplying 100%). Upton a completion of evaluating each study at full-text level, I found 27.27 % of the 88 articles received a score of 6, and 11.36%, and 10.23% of samples received a score of 5 and 4, respectively. In summary, this step eliminated 50% of articles and yields 44 articles remained in the database.

Results

The qualitative evaluation results in a final corpus of 44 articles. Notably, five articles (i.e., Moreno & Reisslein, 2011; Lenzner, Schnotz & Muller, 2013; Schmeck et al., 2014; Leopold et al., 2015; Cromley et al., 2016) included more than one study that meet my research purpose. For instance, Lenzner, Schnotz & Muller (2013) conducted three experiments. In the first study, they provided students graphics with different functions (e.g., informational and representative) and employed eye-tracking technique to evaluate their reading process. Whereas in the second study, they examined the effects of visuals on affective learning. In the third study, they evaluated the effect of using informational and representative graphics together. After a careful evaluation, I included both the first and third study in my analyses. In total, I analyzed 44 articles, including 49 studies.

Descriptive Characteristics of Studies

I first synthesize study characteristics, including participant, content area, and research method.

Study participants. Inclusionary studies included elementary and secondary students. To present findings in a consistent way, I used four designations as follows: kindergarten and lower elementary (K- grades 3), upper elementary (grades 4-6), lower secondary (grade 7-9), and upper secondary (grade 10-12). Except for one study that recruited participants from both lower and upper elementary, the rest focus on only one of these designations. In summary, of the 49 studies, 18.4% (n=9) were kindergarten and lower elementary, 30.6% (n=15) were upper elementary, 24.5% (n=12) were lower secondary and the same proportion studies focus on upper secondary students (n=12).

Content areas. Of the included 49 studies, only three study focused on two disciplines (e.g., a combination of biology and geography). Correspondingly, most of the studies focused on one content area in isolation (n=48). Interestingly, I found over half of studies (54.3%, n=25) researched the effect of visual literacy on science learning and 19.6% (n=9) focused on math. Only a small proportion of studies researched language arts and social studies (15.2% and 6.5%, respectively). This trend highlighted the close connection between visual literacy and STEM education, and addressed the needs for answering my research question, in what ways, graphics tasks could facilitate students' content area learning.

Research method. In terms of research methodology, I found a great majority of visual literacy studies used quantitative method (69.32%), only a small proportion of research applied qualitative research method (23.86%) and mixed method (6.81%).

Synthesis of Studies

To answer the central research question*: in what ways does the incorporation of visual graphic task benefit K-12 students' content area learning?*, I conducted a qualitative synthesis of included 49 studies. The following section encompasses three major themes: (a) graphic design, (b) supporting or scaffolding and (c) learning outcome. Specifically, I first summarize findings using author-provided graphics and student-generated graphics. Then I present studies that focused on instruction or support regarding incorporating visual graphic task with content-area learning. Third, I analyzed the body of included studies, which summarized the learning outcomes related to graphics.

Graphic design. According to Mayer (2014), simply providing students with graphics may not facilitate their learning, and one approach for improving learning with visuals is through material design (i.e., manipulating the presentation of a graphic to optimize learning). As aforementioned, a majority of Mayer's work focus on adults, however, I analyzed studies focused on elementary and secondary students to better capture graphic characteristics in the K-12 context. While researchers agree that graphical design must consider function and form, the exact composition of a well-designed graphic remains disputed (Gatto, Porter, & Selleck, 2011; Lohr, 2008; Kress & van Leeuwen, 1996; Mayer, 2009). Moreover, in response to the effectiveness of graphics with different design, I found previous research findings are mixed. Additionally, as there is no unified taxonomy of graphic types, in this section, I first used broader terminologies to present findings regarding visual design and then discussed how specific graphics affect younger students' learning.

Learning by viewing: using author-provided graphics. I found 53% (n=26) of studies used author-provided graphics, through which student "learn by viewing" rather than "constructing". Author-provided visuals are graphics that are pre-constructed by authors and most typical in K-12 texts. Students do not need to construct their own presentation during the reading process. For example, a pre-constructed visual graphics could be a flow map with color key represent the boreal bird immigration from Canada to U.S. each year. That is not to say that readers are passive when using pre-constructed graphics however, for “When students learn from the pre-constructed graphics, they generate their own understanding by internalizing information” (Vekiri, 2002, p.266).

Within this broad category, researchers used concrete visuals such as photographs (i.e., Segers et al., 2008), pictures (i.e., Acha, 2009; Marley & Szabo, 2010; Arya & Feathers; 2012; Mason, Tornatora & Pluchino, 2013) and images (i.e., Muthersbaugh, Kern & Charvoz, 2014; Leopold et al., 2015) to reduce students’ cognitive load. However, as those graphics usually represented content in the written text, or simply decorated the text (Segers, 2008), they may not effectively reduce text complexity for readers or improve students’ learning as would graphics with functions more aligned with comprehension. For instance, Acha (2009) and Segers et al. (2008) found no difference between multimedia condition and text only condition. One reason may be that Segers et al. (2008) used more decorative visuals, which contained some irrelevant elements, leading to distraction, rather than integration. This finding was further confirmed though analyses of data collected via eye-tracking and oral measurement, in which Arya and Feathers (2012) found that only when students are able to *identify useful information* in visuals and *align visual clues with text* they are more capable of understanding content. Similarly, Mason, Tornatora & Pluchino (2013) grouped students based on the level with which students integrate text and visuals (similar to the alignment described by Arya and Features, 2010). They identified three reading patterns: high, intermediate and low integrators. Further analyses show that the high integrator group outperformed the low integrators both on the immediate recall and factual knowledge test. Overall, these findings revealed that concrete or realistic visuals are effective, only when students could connect visual information with text.

Transitioning to abstract graphics, or schematic visuals, I found that such representations are more widely studied in the K-12 context (n=20) than concrete graphics. In this body of research, abstract graphics were mainly used for organizing information. Compared with concrete graphics, although abstract graphics should reduce irrelevant information, they yielded more inconsistent learning effects. For instance, two groups of researchers (i.e., Moreno & Reisslein 2011; Van Garderen, 2006) directly compared the effects of abstract and concrete graphics. Moreno and Reisslein found the abstract group performs better on the transfer task. However, in another study, Van Garderen (2006) found students who read text with the abstract illustration are able to frequently integrate verbal and pictorial information, although the abstract group and concrete group did not show any difference. This indicates that the abstract graphics may have required more effort on the part of readers but did not facilitate greater learners. Additionally, when compare the effectiveness of abstract graphics with that of text only, findings were also discrepant. In such cases, researchers rarely presented abstract graphics without other forms of scaffolding but worked to promote students' learning by adding a great variety of elements. The results were organized below into four categories.

Adding cues or signals. Researchers have identified specific elements including captions (Cromley et al., 2013b), color codes (Berthold and Renkl, 2009), labels (Mayer & Johnson, 2008), and correspondence signals (e.g., arrows, zoom ins, McTigue, 2009), which can enact such principles by emphasizing relevant information and signaling connections. Although such purposeful design of graphics and texts helps readers build globally coherent mental representations (Mayer, 2014), the effects are mixed.

Adding explanation. Few studies also add explanation to promote students' learning (Segers et al., 2008; Berthold and Renkl, 2009). One way to accomplish this goal is to add researchers' oral explanation, accompanying with visuals and text. For instance, Segers and colleagues (2008) found when presenting fifth grade students both oral and graphic presentations, students produced better short-term performance, despite of their verbal abilities. Another way to promote students' learning is to through supplement materials to facilitate students make sense of, and reflect on the learning task on their own. For example, Berthold and Renkl (2009) found that visual presentation itself did not facilitate students' learning of mathematics concepts, however, add supplemental materials (e.g., self-explanation prompt) would promote learning from graphics. In one of the experimental group, students were provided with self-explanation prompts, which allow them to integrate information from multiple sources on a structural level. Findings show that adding self-explanation prompts foster their conceptual understanding, but not procedure knowledge.

Using materials with analogy. To further facilitate younger students' deep learning and reasoning skills, two groups of researchers provided students materials with prompted explanation of cases. Cromley et al. (2016) added the component through questions about similarities, differences of science concepts, whereas Zheng and colleagues (2008) provided fourth grade students diagrams with analogy, thus students in the analogy group could compare and distinguished the similarities between two electrical circuits diagrams. In both cases, using multimedia with analogy, participants improve science learning.

Using mixed types of graphics. Other researchers provide students both pictorial graphics and schematic visuals (Norman, 2012; Robert, Norman & Cocco, 2015). For instance, Roberts, Norman and Cocco (2015) used captioned pictures, insets, surface diagrams, cross-sectional diagrams, flow charts, timelines, tables, aiming to test the overall effects of visual graphics on students' reading comprehension. Findings from both studies indicated that visual device comprehension is strongly correlated with students' overall comprehension. Furthermore, graphic comprehension contributed to larger variance to the reading comprehension, when compared with other variables, such as reading accuracy and cognitive flexibility (Robert, Norman & Cocco, 2015).

To conclude, although studies above revealed the positive effect of adding explanation, using materials with analogy, using mixed types of graphics, due to the small sample sizes, there is an increasing need for future endeavors to validate these conclusions.

Learning by creating: student constructing graphics. I found 22 studies examined effects of students constructed visuals, and of which, 11 focused on K-6 students. This may indicate a research trend on younger students – frequently, they involved in more complex learning tasks. Interestingly, previous studies did not provide a clear distinction between author-provided graphics and students' generated graphics, although some graphics may fit in both categories. In the following section, I first distinguish two types of student constructing graphics, then present findings regarding visual effectiveness.

Student-filled-in graphics. Multiple groups of researchers provided students with pre-drawn abstract visuals, such as graphic organizers (i.e., DiCecco & Gleasons, 2002; Boulineau et al., 2004; Ciullo, Falcomata & Vaughn, 2015; Ciullo et al., 2015; Sun & Chen, 2016) and incomplete diagrams (i.e., Swanson, 2015). Compared with author-provided graphics, student-filled-in graphics facilitate a more active and involved learning process, because, to complete such tasks, students need to seek and integrate information from both the verbal and visual text. Moreover, they also need to connect the information with their schemas, the prior framework in their mental system, to understand the new concept. Finally, to complete visual tasks they often summarized ideas and use their own language.

Notably, findings from these studies are generally consistent, and indicate that student-completed graphics are beneficial for students with different characteristics. Interestingly, I only found one study focus on typically achieving students (Sun and Chen, 2016) and one for high achieving students (i.e., Gerstner & Bogner, 2009). The majority of studies explored the effects of student-filled-in graphics on learners with different learning disabilities (LD), such as reading deficit (i.e., Boulineau et al., 2004; Ciullo et al., 2015; Ciullo, Falcomata & Vaughn, 2015), math learning disability (Wanson, 2015), and general learning disability (DiCecco & Gleasons, 2002). One reason to account for the trend may be that students with learning disabilities are more likely need additional support when processing information from multiple sources. Student-completed graphics usually contained a pre-determined structure with nodes and key concepts, which provided students scaffolding through material design. Meanwhile, it guides students to eliminate irrelevant information by presenting students the overall structure of a concept or paragraph. Therefore, findings indicate that they are effective and widely used for instructing students with learning disabilities. Through qualitative and quantitative analyses, researchers converged on concluding on the positive effects of such visuals.

Despite the overall agreement of the positive effect of student-completed graphics, research demonstrated that students with learning disability improved learning in different areas. For instance, two groups of researchers (Ciullo et al., 2015; Ciullo, Falcomata & Vaughn, 2015) found students gradually improved discrete content knowledge during graphic literacy intervention. Whereas DiCecco and Gleasons (2002) revealed that students with learning disabilities performed better in application tasks rather than factual knowledge assessments after completing graphics. Therefore, the type of learning that student-completed graphics assist, continues to need more exploration.

Student-created graphics. The last category refers to visuals that were completely generated by students. I found 11 studies filled in this category. Compared with aforementioned graphics, completing these tasks often requires students using higher order cognitive skills and production tasks. For instance, students need to extract information from reading text, justify, apply and synthesize information and finally create the visual graphics on their own or with peers. Probably, due to the complexity of the task, I found researchers were more interested in investigating the issue with a focus on upper elementary and older students, assuming older students already acquired basic literacy skills. Findings from the included studies were consistent, revealing that students significantly improved their content-area learning when creating diagrams (i.e., van Garderen, 2007; Cromley et al., 2013a), concept map (i.e., Kwon & Cifuentes, 2009; Wang, Huang & Hwang, 2016), mixed graphics (i.e., graph, pie chart, diagrams, Terwel et al., 2009) and pictures (i.e., Cohen & Johnson, 2012; Schmeck et al., 2014). In total, this intervention seems highly promising for promoting learning with upper elementary and older students.

However, current research provided only limited insight regarding younger students' learning process and visual effects from creating graphics. As evidence, I only found two studies focused on lower elementary levels (K-3, Enyedy, 2005; Cohen & Johnson, 2011). Enyedy (2005) addressed the importance of activities. Specifically, in the study, second and third grade students improved their content learning through creating maps, accompanying with a set of activities, such as problem identification, group discussion and collaboration. Students inventing solutions and producing maps to solve the problem. In another study, Cohen & Johnson (2011) focused on how visuals facilitate student basic literacy skills, as they examine students' recalling of science terminologies through a process of image creation. Findings indicated a significant difference between the image creation group and the text-only group. Therefore, these findings suggest a benefit for younger students, but more research is needed.

It is important to provide a caution to these results: While having students create graphics yielded large learning benefits, it also require a complex set of skills, thus, students are more likely to need additional support or instruction. Therefore, these findings do not recommend simply assigning such a task to students, but for teachers to follow an instructional sequence with graduate release including modeling and providing feedback. Moreover, even when students study author-provided graphics, without corresponding skills, completing visual literacy tasks can be very challenging. Therefore, in the next section, I synthesize included studies and present various intervention that were used to facilitated K-12 students' learning.

Support for students' content area learning. With the increasing complexity of visuals in K-12 curricula, research has shifted from investigating the simple effects of visuals on students' learning to examining the extent additional intervention/support promote their learning. In total, I found almost half of the included studies provide students support before or during visual literacy intervention (n=23). These activities are varied in three dimensions: content, strategy, and duration.

Content. The focus of interest in a large body of exploration was directed toward literacy instruction, content specific instruction, and visual convention instruction.

Instruction on basic literacy skills. Two groups of researchers worked to promote students' learning by delivering instruction on basic literacy skills prior to using visual elements. For instance, Boulineau and colleagues (2004) delivered explicit instruction on story-grammar. Thus, students demonstrated skill of recognizing story components such as setting, characters, and identifying connections among story components before using a graphic organizer which capture such information, which further facilitated their reading comprehension. As such the story map served as a tool to record and organize previously taught information. Compared with Boulineau et al. (2004), in DiCecco & Gleason's (2002) study, teachers delivered instruction not only on the reading comprehension strategies (e.g., inference) but also on vocabulary and decoding skills. As students are familiar with vocabularies and reading strategies, they are more likely to distribute energy on analyzing and processing information when use graphic organizers. Findings revealed that proving literacy instruction before using graphic intervention is particularly effective for K-12 students with learning disabilities, but we need more future research to confirm this conclusion.

Visual convention instruction. Researchers also investigated instruction on visual convention, especially for students using diagrams (i.e., Cho & Jonassen, 2012; Cromley et al., 2013b; Bergey et al., 2015; Swanson, 2015) and graphic organizers (Ciullo, Falcomata & Vaughn, 2015). However, not all studies directly compared students who received visual convention instruction with those who *only* used graphics. Frequently, it accompanied other intervention for both group in the same study. Thus, it's difficult to generate a conclusion regarding the impact of visual convention instruction. For instance, Cho & Jonassen (2012) compared three interventions: instructional explanation, self- explanation, and meta-level feedback. Because students in all of these three conditions received instruction on visual convention (e.g., how to interpret diagrams), we are unable to make any inference regarding the pure effect of instruction on visual convention. Only two studies provide more insight regarding the effect of Visual convention instruction. In Cromley et al.'s (2013b) study, teachers provide diagram conventions tips to students in the experimental group, which allows them to understand declarative knowledge (e.g., how to interpret color keys in diagrams) and procedural knowledge (e.g., when to interpret a specific part in a diagram). Students then worked in workbooks to practice those strategies. Unlike the experimental group, students in the control group occasional received demonstrations of what the diagrams mean, but no workbook was provided. Findings indicated that students received convention of diagram presented greater growth in diagram comprehension. Similarly, Swanson (2015) compared students in four conditions: verbal strategies, visual strategies, both verbal and visual strategies and untreated group. Students in the visual strategies group were taught how to use and fill in two types of diagrams (similar to procedural knowledge in Cromley et al's study). Findings demonstrated that for students with math disabilities, but high working memory span, using visuals was beneficial for the working memory transfer task. However, the results did not yield any significant finding on problem solving task when using visuals.

*Content-area specific instruction***.** Investigation of content-area instruction focus on three disciplines: mathematics, science and safety education (e.g., Kwon & Cifuentes, 2009; Terwel et al., 2009; Moreno & Reisslein, 2011; Cromley et al., 2016; Sun & Lee, 2016). Particularly, researchers using different instructional methods to teach content specific concepts, prior to using visuals. For instance, Cromley et al., (2016) used case comparisons to highlight key science concepts. Sun & Lee (2016) asked students questions regarding concepts of anti-phishing and instructed them to poll and discuss answers after scanning the passage. Terwel et al. (2009) have students work in a creative manner by instructing them to connect math problems with real-life situations, then students learnt to recontextualize mathematic concepts and strategies in different contexts. In Moreno & Reisslein's (2011) study, students take a lesson which shows the meanings physics concepts followed by explicit examples showing the application of principles (e.g., Ohm's Law). Through a series of instruction on content area, students are more likely to understand the correlation of concepts and construct the mental framework. Therefore, later when they use graphic organizers and diagrams, researchers found such practices would benefit students' understanding and problem solving.

Strategies/Activities. In the body of research on the impact of visual literacy for K-12 students' content area learning, I also found researchers designed a series of activities to guide students' use of graphic devices. In summary, these activities encompassed instructional feedback, peer collaboration, meta-cognitive strategy.

Instructional feedback/ guided practice. Multiple groups of researchers consider teachers' instructional feedback as an important way to promote students' content area learning when using graphics within the instruction (e.g., Swanson, Lussier & Orosco, 2013; Cromley et al., 2013a; Bergey et al., 2015; Swanson, 2015). Specifically, teachers often asked probing questions (Bergey et al., 2015) or delivery instruction on the procedure, and/or content and visual convention knowledge (e.g., Swanson, 2015; Swanson, Lussier & Orosco, 2013). Then students worked on exercise to practice those strategies. Most importantly, teachers provided *feedback* to clarify the confusion that student generated in the exercises, or correct those misunderstanding to promote students' in depth understanding. When providing with such feedback, students learnt how to apply strategies and deal with learning tasks correctly. Finally, they used visuals and text and apply those strategies in an independent practice.

Peer collaboration. Another way to promote students' learning with visuals was through peer collaboration. To date, convergent findings from included studies addressed the positive effects when students work in pairs or groups to complete visual graphic tasks (e.g., Enyedy, 2005; A° berg-Bengtsson, 2006; Gerstner & Bogner; 2009; Terwel et al., 2009; Sun & Lee, 2016). These positive findings may be due to the fact peer collaboration allowed students to share and discuss the representations of their mental structures in an interactive manner. Additionally, according to Kwon and Cifuentes (2006), students worked collaboratively allows them to improve their knowledge construction. Findings show that the peer collaboration group outperformed students who worked individually on creating higher quality concept maps, indicating in-depth conceptual understanding.

Self-explaining and meta-cognitive strategy. For students who work individually to complete visual tasks, teachers also facilitated their content area learning by teaching them meta-cognitive strategies, such as self-explaining (e.g., Cho & Jonassen, 2012; Berthhold & Renkl, 2009; Norman, 2012; Cromley et al., 2013a). Self-explaining refers to "an activity that students make sense of new information either presented in a text or in some other medium'' (Chi 2000, p. 164). This strategy allowed students to interpret and understand new information presented in text and visuals, as well as monitor their reading process. For instance, in an interactive manner, Norman (2012) had younger students use think-aloud method to orally explain ideas and share their thoughts during reading. Findings indicated that students' graphic comprehension was strongly correlated with students' overall reading comprehension.

However, as Cho & Jonassen (2012) revealed self-explanation effect can be reduced by misunderstandings. That is, sometimes, students may generate incorrect interpretation based on their prior knowledge or false impression. Therefore, to reduce the limitation of self-explanation, researchers (Cho & Jonassen, 2012; Berthhold & Renkl, 2009) also instructed students to use meta-level feedback together with self-explaining. In this way, students were able to compare their responses with instructional explanations, which was previously taught by teachers, and finally reflect on their explanations of text and graphics. Findings show that students in the meta-level feedback condition outperformed those in self-explanation and instructional explanation conditions on recall and inference tasks (Cho & Jonassen, 2012).

Although research methods vary, these studies sought a deeper understanding of how to use activities or interventions in a more effective manner to promote K-12 students' learning from multimodal texts across disciplines. To conclude, this is a useful direction for future research, but we need more studies to compare the strength of different interventions (e.g., instructional feedback versus peer collaboration) to clarify when and how these interventions are effective. Furthermore, we need more qualitative studies to investigate learning process, especially how students used these strategies to improve learning.

Duration. Notably, these interventions also varied in duration. Some researchers provide students short-term intensive training, whereas others promote students' learning in a more comprehensive way, aiming to enhance the learning through long-term intervention.

Short-term intensive instruction. Short-term instruction usually occurred before intervention, aiming to provide a general procedural knowledge for students. This step can be very important for students who are unfamiliar with experiment procedure or lacking experiences in working in multimedia environment (e.g., A° berg-Bengtsson, 2006; Moreno & Reisslein, 2011). For instance, in Moreno and Reisslein's (2011) research, tutors only delivered students one lesson on procedural knowledge regarding online program, afterward, students learn a diagram depicted in the problem.

Long-term training. Compared with short-term instruction, long-term training varied in formats, but in general, teachers presented rigorous lesson plans as related to content with visuals embedded within the instructional sequence. Usually, teachers delivered instruction step by step in each lesson, and repeated the same procedure in the next session (Miller, Cromley & Newcombe, 2016; Bergey et al., 2015; Cromley et al., 2013b; Swanson 2015; Cromley, 2016).

For instance, in a recent study (Swanson, 2015), teachers delivered 20 lessons over 8 weeks on the topic of calculation of mathematical problems using verbal, visual or both verbal and visual strategies. The training is very comprehensive, including warm-up, instructional intervention, guided practice, and independent practice. Students in the visual strategy group were taught how to use diagrams to solve problems. Similarly, Cromley et al. (2013a) also provided students multiple lessons over 6 weeks. In each lesson, teachers first delivered instruction, and then students worked in groups on worksheets, with scaffolding from the teacher. Finally, the teacher provided feedback on students' answers and explained those incorrect items. Long-term training allows students more time to process the information that they learnt in the previous lesson. Therefore, through a series of repeated training, they strengthen knowledge on visual convention, reading strategies and content knowledge.

Learning outcome. According to Mayer (2002), visual graphics usually promote higher-level learning such as problem-solving, rather than recalling. Again, these findings are consistent for college students, however, it provides little insight when we attempt to translate Mayer's principles to younger readers. Therefore, through a systematic review of research on K-12 students, the following section will center on different levels of learning outcomes across disciplines. Specifically, I borrowed the taxonomy from Bloom (1956) and Anderson et al. (2000), to summarize the impact of visual literacy on students' cognitive learning.

Remembering. I found three studies measured students' retention of vocabulary (Acha, 2009; Cohen & Johnson, 2011; 2012). Interestingly, all these studies centered on younger students (e.g., kindergarten and elementary students). Acha (2009) and Cohen & Johnson (2011, 2012) access students' memorization and retention of science vocabulary after imagery interventions. Findings indicated that using graphics significantly improved students' recalling of vocabularies, when compared with students in the text only condition.

However, the effects are mixed when researchers measured students' retention of factual content knowledge and main ideas of text (DiCecco & Gleason, 2002; McTigue, 2009; Mason, Tornatora & Pluchino, 2013; Zheng et al., 2008; Cho & Jonassen 2012). The mixed effect may due to various factors such as treatment effect, and the extent students are capable to integrate text and graphics. For instance, DiCecco & Gleason (2002) and McTigue (2009) found no differences between treatment (e.g., using graphics and text) and control condition (e.g., using text only) in factual knowledge retention tasks. However, Cho & Jonassen (2012) demonstrated that when students are able to use meta-level feedback during reading, they outperformed students who use other strategies (e.g., instructional explanation or self- explanation) on recall and inference tasks. Similarly, Zheng et al., (2008) revealed when used multimedia with analogy, students demonstrated highest performance on retention of factual and procedural knowledge among all groups. Therefore, I may conclude that simply using visuals may prompt students' recalling of vocabularies, but may not directly improve students' recalling of knowledge.

Understanding. A great number of studies (N=22) focus on the impact of visual graphics on students' reading comprehension (e.g., McTigue, 2009; Cromley, 2013a, 2013b). Specifically, these studies measured *when, how* and *why*, graphics could promote elementary and secondary students' literal and inferential comprehension. However, findings regarding the effect of visual literacy on reading comprehension are very controversial. As aforementioned, the miexed effect may due to many factors, such as intervention effect, graphic design. For instance, in multiple cases, students received instruction on procedural knowledge and content specific skills, which allowed them applying various strategies to integrate information from multiple sources (e.g., Cromley, 2013b; Cho & Jonassen, 2012), whereas other attempted to facilitate students' understanding though graphic design (e.g., McTigue, 2009; Leopold et al., 2015). Furthermore, students' characteristic is another important factor that moderate the impact, such as their prior knowledge, attention and reading skills. Data collected via think-aloud method and eye-tracking technique may provide us in-depth understanding of this complexity. According to Jian (2017), compared with less-skilled readers, skilled readers spent significantly more effort and time on both text and graphics, and intended to process the article holistically. Moreover, they are more likely to integrate the corresponding information from multiple sources during reading.

Another factor that account for the mixed effect maybe assessment format. Reading comprehension can be measured through different tasks: cloze, short answer questions, multiple choice questions, or drawing. For instance, to measure students' comprehension of the conceptual information, Schmeck et al. (2014) have students to draw the main ideas given in the science text. Whereas in most cases (e.g., McTigue, 2009, Cromly, 2012b), reading comprehension was measured through standardized tests such as multiple-choice questions. Although researchers attempted to measure students' comprehension, tasks such as short answer and drawing are likely to involve more cognitive demand than t/f or multiple-choice questions. However, to validate this conclusion, there is an increasing call for future research to test students' reading comprehension via different forms of measurements.

Applying, Analyzing & Evaluating. Although Bloom (1596) and Anderson et al. (2000) distinguished the three levels of learning (i.e., applying, analyzing and evaluating). In the field of visual literacy, I found researchers often measure these three levels of learning through a single test. For instance, when handling a mathematic problem, students need to analyze information and evaluate the accuracy of information, then integrate relevant information from multiple sources, and finally transfer knowledge and apply it to solve the problem. Therefore, I consider these skills as an integrity in this section.

Interestingly, I found researchers frequently use visual literacy to promote students' transfer, evaluation and application of knowledge and principles in STEM education, such as mathematics (e.g., Pyke, 2003; Van Garderen, 2006; Elia, Gagatsis & Demetriou, 2007; van Garderen, 2007; Berthold and Renkl, 2009) and science (Science Enyedy, 2005; Segers et al., 2008; Zheng et al., 2008). In most cases, the effects are positive. For instance, van Garden (2007) conducted an experiment on 6th grade students and revealed that use of visuals was positively correlated with better performance on mathematical problem–solving tasks. However, according to Elia, Gagatsis & Demetriou (2007), this effect may be moderated by students' age and graphic design. In a study, they analyzed 1447 first-, second-, and third- grade students' performance in a large-scale math assessment through structure equation modeling. The results indicated that the type of representation (decorative, informational, number line) moderate students' mathematical problem-solving performance. However, it is revealed that the way students handle representations changes with age. Moreover, when compared with decorative graphics, informational pictures may hinder younger students' problem-solving, as they may require more complex mental processes. It is important to note that I only identify one study used large scale test, therefore the findings should be interpreted with caution.

Creating. Creation is considered as the most complex task in Bloom's (1954) taxonomy. When aligning the taxonomy with the current research, I found in most cases, students need to create graphics on their own or with peers. Again, as aforementioned, teachers frequently instructed students with a series of scaffolding activities on content and visual conventions. When students acquire corresponding skills, and are able to apply those strategies in higher level learning tasks, create graphics yielded large learning benefits.

Discussion: Connecting Theory to Practice

When evaluating empirical studies within visual literacy and content-area learning, I found three predominate theoretical framework as follows: dual coding theory, cognitive theory of multimedia learning, schema theory. In this section, I will connect those theories with empirical studies to interpret the impact of visual literacy for learning.

Dual coding theory (DCT) postulates the cognitive process of encoding and extracting information. According to DCT (Clark & Paivio, 1991), information is processed in two distinct forms: verbal and nonverbal. Information presented in nonverbal form is more concrete. Therefore, if students could utilize the verbal and nonverbal routes to process and restore information, they can more easily retrieve knowledge the long-term memory, thereby reduce cognitive load. Hence, the presence of visuals along with text has additive benefits for learning. The cognitive theory of multimedia learning (CTML): CTML (Mayer, 1989) was originally an extension of DCT, which also assumed that students had limited cognitive capacity. Compared with DCT, CTML specifically predicts students' learning in multi-modal environments particularly in a computer-based environment. Learning is an active process of information-election, -organization and -integration.

However, when aligning DCT with research findings on author-provided concrete graphics (e.g., pictures, photos, images), I found the results did not fully support the theory. Specifically, the findings on concrete and abstract graphics (or pictorial and schematic graphics) are mixed, which means that simply providing learner graphics will not result in direct positive learning effect. Eye-tracking and think aloud data shows that only when students are able to select, integrate, and synthesize information from multiple sources, graphics can be more effective.

In addition to this complexity, counter to multimedia learning principles (Mayer, 2002) which demonstrated that graphics would benefit students' higher order learning skills, findings revealed that the effect is mixed. When providing with visuals, students have better performance on recalling of vocabulary, but the effects on retention of factual knowledge is mixed. Furthermore, although in most cases, visual graphics promoted students' higher-level learning, such as analyzing and evaluating information in multimodal text, transferring knowledge and applying strategies to solve problems, it is important to note in many cases, teachers delivery instruction to assist students deal with these complex learning tasks.

Studies focus on student-fill-in and student-generated graphics frequently are connected with schema theory (ST), which suggested that our mental system contains frameworks with slots for specific information (Rumelhart, 1980). When facing new information or principles implicit in text, students could use prior well-developed schema to make sense of those new information. Therefore, research indicated that graphic organizers are useful for activating readers' prior knowledge and they help students to understand text structure and build connection among concepts. When connecting ST with empirical research, I found student- fill-in and student- generated graphics largely promote students' learning in most cases. Especially, they are beneficial for students with learning disabilities, who used graphic organizer as a tool for scaffolding.

Limitation

As the study applied systematic literature review as the methodology, it has several inherent limitations. First, although the review reported certain quantitative information associated with the qualities of included studies, the numerical information is not as clear and in depth as those generated from meta-analysis. Secondly, the qualities of included studies may be another limitation; however, the limitation can be diminished by employing the quality indicators, using the inclusion criterion of selecting studies appearing in peer-review journals and dissertations through the double coding process by two raters. In addition, because the scope of the study focuses on impacts of visual graphics on K-12 student's learning, the interpretation should be cautious, and the result cannot be generalized when interpreting the impacts of visual graphics on college students' learning.

Direction for Future Research

Three topics warrant consideration for future research regarding when, how and for whom graphics are most effective for learning across disciplines.

For whom. The research on how English language learners interacted with multimodal text is very dearth in the field, as I only identify one study exploring the visual facilitation for English language learners. Although the existing literature frequently demonstrated the importance of visual strategies to improve ELLs' reading comprehension (Watkins & Lindahl, 2010), limited empirical studies were conducted with this population. Moreover, as multimodal text in lower elementary textbooks becoming increasingly complex, there is a need to learn when and how to integrate visual literacy with younger readers' learning across disciplines.

How. The research topics regarding visual literacy have shifted from investigation on graphic design to exploration on instruction and training for K-12 students. In general, these studies provide in depth insight regarding the effect of teachers' explanatory instruction. However, limited studies focus on very specific strategies, especially *how* student use explanatory and metacognitve strategies during reading and *when* it promotes their learning. For instance, Berthold and Renkl (2009) compared three reading strategies (e.g., explanatory instruction, self-explain strategy, and meta-level feedback), revealed that graphics are most effective, when students are able to use self-explain and meta-level feedback together. Therefore, more studies are needed to replicate these principles and examine the instrument validity. Furthermore, when design instructional activities, researchers also should consider students' prior knowledge, such as procedural knowledge, visual convention, and content specific knowledge. Therefore, it is important for future endeavors to further investigate these factors and provide more support for younger students.

When. When examining those 88 articles using the methodological quality indicators, I found a majority of quantitative studies used standardized tests to measure different levels of learning. However, in many cases, researchers did not report the reliability or validity of these measures. I want to highlight the importance of instrument reliability, as they could directly moderate the findings. For instance, in a previous study, when researchers used three comprehension assessments to identify struggling readers, they found using three standardized tests could yield very different results. Therefore, I encourage future researchers to develop and use reliable measurements (or at minimum report reliability statistics) when accessing students' learning. Moreover, a majority of the studies used quantitative method and I only found 6 mixed method studies. Therefore, more expansive studies are needed by collecting data from multiple sources, provide insight regarding students' learning process across disciplines.

Conclusion

In this review, I addressed the complexity of incorporation of visual literacy with content area and disciplinary learning. Therefore, provided future endeavors with a fundamental understanding of the trend of research in visual literacy.

Through a systematical review of empirical studies, this study aimed to answer: "*In what ways does the incorporation of visual graphic tasks benefit K-12 students' content area* *learning?".* I first synthesized previous research, distinguished three types of visual graphics, named author-provided, student-fill-in, and student-generated graphics. Through a comprehensive evaluation of these graphics, I discussed their effectiveness on students' learning across disciplines. I also analyzed data collected via think-aloud method and eye-tracking technique aiming to provide in-depth understanding of this complexity. In summary, I found that simply using graphics do not guarantee a positive learning effect. To promote students' learning, teachers could provide support to guide them acquire multiple skills to integrate information from multimodal text.

Therefore, I evaluated the intervention from previous research in visual literacy and content area learning, result in analyses guided by three categories: content, strategies and duration. Last, I analyzed students' learning outcome, and found that visuals could promote younger students' recall of vocabulary, but the findings regrading retention of content knowledge is mixed. Moreover, counter to Mayer's findings, the current review demonstrated a mixed effect of graphics on K-12 students' higher-order skills (e.g., problem solving). Compared to adult readers, in addition to the benefits, younger students may encounter more challenges when learning from multimedia texts. It is important to emphasize that with teachers' instruction and support, visuals and strategies combined can promote higher-level learning.

CHAPTER V

CONCLUSION AND IMPLICATIONS

In this conclusion chapter, I first summarize key findings from each of the three studies. Then I connect the findings from these three studies and present them by themes for the purpose of implication for future research.

Chapter II, *A Content Analysis of Visuals in Elementary School Textbooks* informs the field by examining the characteristics of graphics in elementary authentic textbooks. Previous efforts towards this goal were dated (Fingeret's, 2012) and did not reflect the current visual reality of today's texts. Moreover, through a systematic evaluation of the graphics in third- and fifth- grade students' science and social studies textbooks, I created a workable taxonomy to classify graphic type and function. One important finding from this work is that younger students encounter a great range of graphics while reading informational text. This finding informed that it would be useful to examine the research base examining the impact of graphics on student learning across disciplines. As such, I conducted a systematic review, which is presented as two stand-alone studies.

Chapter III, *Critical Analysis of Research on the Impact of Visual Literacy for Learning: Strengths, Weaknesses and Recommendations for Improvement*, provided researchers insight regarding the strength and weakness of current research on impact of visual literacy on learning in K-12 context. I modified previously established methodology quality indicators (Risko et al., 2008; See Miller, Scott, & McTigue, 2016) to allow for more rigorous assessment of qualitative and mixed-method study. Then using this tool, I assessed the quality of previous empirical studies on visual literacy and content-area learning that published between 2002 and 2017. This step yielded a final corpus of 44 articles (49 studies) in the database, and identified patterns of strength and weakness in the research field of visual literacy.

Finally, Chapter IV, *Research on the Impact of Visual Literacy for Learning across the Disciplines: A Systematic Review*, synthesized the 44 pre-screened articles. The primary goal of this study is to determine in what ways the incorporation of visual graphic tasks benefit K-12 students content area learning. I first distinguished between the author-provided graphics (which is the main focus of Chapter II) and students' created graphics. By presenting the characteristics of graphics that students encountered across studies, I further analyzed that training or support that provided by teachers to promote students' learning across disciplines. Finally, borrowed from Bloom's (1954) taxonomy, I analyzed the impact of visual literacy on different levels of learning.

According to RAND (2002), students' reading outcome are affected by three important factors: reader (K-12 students), text (which includes visual and verbal text), and activity (teachers' instruction and students' reading strategies). Considering these three factors in unison, the present studies focused on the characteristics of visuals in authentic textbooks as well as in current research, and instruction that promote visual literacy for K-12 students' learning across disciplines. In general, research shows that students often require more explicit instruction when using multimodal text. Therefore, the current studies helped to explain challenges that student frequently encountered when using graphics, and the current research trend in visual literacy. In summary, these three studies present two key conclusions for visual literacy researchers and practitioners: (a) the characteristics of visual graphics in K-12 curricula; (b) the impact of visual literacy for learning across disciplines (*the connection between research and practice*), and instruction that promote visual literacy for K-12 students' learning.

Characteristics of Visual Graphics in K-12 School Texts

Previous research demonstrated that well-designed graphics could promote students' learning (e.g., Carney & Levin, 2002; Hannus & Hyona, 1999; Haring & Fry, 1979; Mayer & Gallini, 1990). However, there has been standard typology system of visual graphics in the field. This creates situation not just of inconsistent vocabulary, but also for conflicting systems. For instance, relying on the characteristics of visual graphics, Hegarty, Carpenter, and Just (1996) classified visuals into three categories as follows: iconic diagrams, schematic diagrams, charts, and graphs. According to the classification, both flow map, and Venn diagram are schematic diagrams, whereas based on Moline's classification system (2001), they belong to different categories. Therefore, in Chapter II and IV, we examined the types and functions of visuals. Specifically, Chapter II focused on graphics in elementary school text, whereas Chapter IV analyzed the graphics that were mainly designed by researchers, including researcher-designed visuals and those selected from textbooks with modification.

Types of Graphics

In Chapter II, I expanded Fingeret's (2012) dissertation work by evaluating graphics from textbooks that adopted by both Common Core Standard and Texas State Standards. According to Chapter II, in total, I found that there were nine major types of graphics (e.g. diagrams, images, photographs, flow diagrams, maps, tables, pictures, and charts) and 54 sub-type of graphics present in the 3rd- and 5th- grade social studies and science textbooks. Additionally, the types of graphics are significantly different from each other when comparing social studies and science textbooks. However, as aforementioned, this study only focused on author-provided graphics and a limited number of student-completed graphics. Chapter IV diversified the sample by evaluating graphics which were designed by researchers in addition to those selected from text books.

Moreover, it focused on visual graphics across K-12 disciplines, including ELA, mathematics, science and socials studies. When connecting research to practice, I found over half of studies researched the effect of visual literacy on science learning and 19.6% focused on mathematics. This may indicate a research focus on incorporate visual literacy with STEM education. Only a small proportion of studies researched English language arts and social studies. Findings indicate that social studies texts, contain a large variety of visuals, so it is curious that so few studies have focused on this discipline.

Furthermore, among those 49 studies, diagrams and graphic organizers were widely used to promote students' learning. However, according to Chapter II, photographs and images are the most prevalent visuals in students' textbooks. This may indicate a discrepancy between research and classroom practice, or it may reflect that the materials that we provide to students for reading and those that we provide for classroom learning opportunity are not well aligned. The high use of photographs, but relative absence in research is particularly notable.

In total, these two findings provide implications for implications for future research. Specifically, it is important address a need for examining the impacts of most common types of graphical displays (e.g. photograph, image, diagrams, maps, charts) on K-12 students' learning. Additionally, the discipline specific research should be expanded into ELA and social studies.

Functions of Graphics

Chapter II evaluated six main functions of visuals in elementary social study and science texts, named *decorative, representative, organizational, interpretational, transformational, and extensional*. Findings revealed that most of the graphics in science textbooks serve as representations (64.1%), meaning they provide a concrete example to support the text. As noted above, photographs, which dominate the visuals frequently serve in this function. However, Chapter IV documents that the majority of graphics in research function for the purpose of organization. This finding may be due to the correlation between function and form - researchers frequently used diagrams in the study, which are frequently used for organizational purposes (e.g., a water cycle diagram).

Furthermore, findings from Chapter III indicated that in total, 42.01% of the visuals in third and fifth– grade textbooks contained new information. Among them, the majority (73.4%) provided information clearly linked to the text, which would be easy for students to interpret. However, as Chapter IV demonstrated many empirical studies did not provide a sample of material, making it difficult to identify whether there was an overlap of material or not in the investigated graphics, or with what level of explicitness the graphic and text were connected. Therefore, such information is missing in selected studies.

To conclude, the findings from Chapter II and Chapter IV indicated there is a discrepancy between research and classroom practice regarding how to utilize those graphics. Specifically, in a meta-analytic study, Carney & Levin (2002) examined the extent that the five major functions of graphics moderate the impacts of graphics on students' learning. Results indicated that transformational graphics are the most beneficial visuals for students' learning (d=1.4). However, Chapter II shows there is little incorporation of transformational graphics in the 3rd- and 5th-grade school texts. Moreover, Carney determined that compared with interpretational (d= 0.75) and organizational (d= 0.7), representational graphics have less impact on students' learning *(d*=0.5), however, in school textbooks, a majority of graphics (n= 60.9%) served as the representational function. These findings call for more research on functions of graphics and how function interacts with student learning.

Impact of Visual Literacy for Learning across Disciplines

Although pictorial graphics (concrete graphics) are widely used in school curricula, findings regarding the effects are very discrepant in the field. To provide more insight regarding the impact of visual literacy for learning across disciplines, I conducted two studies. Chapter III served as an important screening step for Chapter IV, because it allows us to include empirical studies with most rigorous design.

Through a systematic evaluation of study methodological quality in Chapter III, I included 44 articles for the qualitative analysis, of which, 69% are quantitative studies, and 24% are qualitative studies. Only 2 studies adopted mixed methods approaches. Based on the qualitative analyses in Chapter IV, I found the effects of author-provided graphics are mixed. According to eye-tracking and think-aloud data, graphics are effective only when students are able to apply skills to integrate visuals and text while reading. Therefore, many researchers attempted to facilitate students' learning through graphic design and other enhancements: a) adding cues and signals in schematic graphics; b) using oral explanation accompanying text and graphics; c) provided students materials with prompted explanation of cases, such as analogy and self-explanation prompts; d) using mixed types of graphics. All these methods aimed to provide students scaffolding and to promote more interactive learning.

In terms of student-completed graphics, findings from Chapter IV indicated student-filled-in graphics are widely used for students with learning disabilities and in most cases, largely facilitated students' learning. However, it is important to note that in many studies, teachers frequently delivered explicit instruction on literacy strategies, visual convention and content-specific knowledge, which helped students to select, evaluate, and analyze relevant information form multimodal text. Therefore, these graphics worked in a highly supported context, and it is difficult to discern which aspect of the context most supported learning.

For students-generated graphics, Chapter IV revealed that researchers are frequently incorporated such intervention with STEM education. The overall findings showed they are beneficial for students in acquiring higher level learning skills, such as problem solving, and creation of graphics. Moreover, convergent research also demonstrated that younger students often face challenges when learning multimodal text across disciplines. Therefore, researchers also investigate seek strategies to support students' learning, such as (a) instructional feedback, (b) peer collaboration, (c) meta-cognitive strategy. A majority of studies compared students who used a specific strategy with those in the control group, however, few studies compare the effects of different strategies, which provide little insight regarding when and how these strategies are effective. These findings provide important implication for future research and call for more investigation to understand the interaction between graphics and active learning strategies, as well as to compare different active learning strategies.

Learning Process

As demonstrated in Chapter III, I only identified few studies that used think-alouds and eyes tracking technique, through which, researchers could explore the process of how students interact with graphics and text. For instance, in Chapter IV, I found students the high-integrator outperforms low integrator groups in factual knowledge and recalling, which further explain why the findings on author provided graphics are mixed. Moreover, through a systematic coding of think-aloud data, Norman (2012) shows how younger students make sense of visuals and text, which further revealed that the visual comprehension has a positive correlation with students' overall reading comprehension. These studies provide us more insight regarding students' reading process.

Another way to study students' learning process is through qualitative research methods. For example, researchers can analyze data from multiple sources, such as teachers' interview, researchers' field notes, students' survey. All of these research methods provide valuable information and promote in-depth integration of the complex issue. However, according to Chapter III, there is limited number of both qualitative study and mixed method study. Thus, there is a call for research to collect data from multiple resources to enrich the findings on the impact of visual literacy for learning.

Learning Outcome

More frequently, researchers investigate how visuals affect students' learning outcome. Therefore, borrowing Bloom's (1954) and Anderson et al.'s (2000) taxonomy, Chapter IV discussed the impact of visual literacy on different levels of cognitive learning (i.e., remembering, understanding, analyzing, evaluating, apply and creating). Findings from Chapter IV only partially confirmed Mayer's (2002) conclusion. According to Chapter IV, providing students graphics would facilitate their recalling of vocabularies, but not retention of content knowledge. Furthermore, in general, using graphics are beneficial for students' higher-level learning. However, we need more studies that adopted large scaled assessment to validate those conclusions.

Implications for Future Research

To conclude, the current research provided several important implications for future endeavors. These implications were generated into two themes: (a) research trend, and (b) methodological quality.

Research Trend/Topics

- Although using student-created graphics frequently facilitate younger students' higher-level learning in general, notably, in most cases, teachers provide instruction before or during intervention to ensure students acquire corresponding skills.
- Although in many cases, teachers provided instruction on (a) visual convention, (b) reading skills and (c) content specific knowledge, limited studies provide insight regarding how specific instruction affects learning outcomes.
- More research is needed to explore the extent using specific strategies (self-explanation, peer collaboration, meta-cognitive skills) in conjunction with visuals enhances learning from visuals.
- There is limited research focusing on younger students (K-3), who are also more likely to encounter challenges when using multimodal and complex text.
- Most of the included studies highlight the importance of native speaker' learning process associated with visual literacy, there is a dearth of studies on how ELLs correspond with multimodal text.
- Although the research trend shows that an increasing number of studies adapted the materials from authentic text. Overall, the graphics in research did not reflect the complexity of visuals in students' textbooks.

Methodology Quality

- There is a need for mixed method studies, because collecting data from multiple sources allow researchers to better understand student' reading process, and how the reading process is associated with different levels of learning.

- Findings revealed that a great number of studies did not report the instrument reliability and validity. Future research should provide more details regarding instrument development.
- We also need more quantitative studies with larger sample size to validate those conclusions regarding the impact of visual literacy for learning across disciplines.

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APPENDIX

FULL GRAPHICAL TYPE CODING SCHEME AND DEFINITIONS

Type	Sub-Type	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 which 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
	Cut-Away diagram	A 3D 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 which do not feature any of the other defined characteristics
	Scale Diagram (Picture)	Diagrams showing the size of something in comparison to 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 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/Though 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

	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
	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
Timelines – Visually organize events in time	Simple Timeline	Shows events in a linear organization
	Multiple Timelines	Two or more timelines showing events occurring at the same time in different contexts