THE RELATIONSHIP OF READING STRATEGIES AND CONTENT KNOWLEDGE IN MODELS OF INTEGRATED INSTRUCTION

by

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To Delaney and John Nick, with love.

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ABSTRACT

Integrating reading instruction and content area curriculum has been suggested as a method of improving students' reading comprehension and access to content knowledge. Less clear are the specific practices that should be used across the curriculum to improve comprehension and build knowledge simultaneously. The two studies in this dissertation use different methodologies to contribute to a body of research on how to best integrate reading strategy instruction and content learning to improve both reading comprehension and general academic achievement. The first, an experimental design, seeks to determine the effect of teaching inferential strategies while building knowledge using informational text. The second uses meta-analytic techniques to determine if the practice of integrating science and literacy instruction is associated with higher effect sizes, both overall for measures of science and literacy achievement, and when particular literacy and science practices are present in the intervention. Both studies seek to systematically answer questions about the relationship of background knowledge, reading comprehension, and content learning.

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CHAPTER I

INTRODUCTION

More than a decade of educational policy and resulting data suggests that adolescent literacy instruction remains a challenging task. Though the 2017 National Assessment of Educational Progress (NAEP; National Center for Education Statistics, 2017) reported slight improvement in grade 8 test scores from 2015 to 2017, it still remains that 65% of eighth-grade students were not proficient in the comprehension of grade-level text. Similarly, the Programme for International Assessment (PISA; OECD, 2016) reported the average Reading Literacy score of American 15-year-olds was significantly lower than peers in 14 other countries. The two studies in this dissertation are intended to add to a body of literature addressing the most effective ways to support readers who have mastered the word-level domain of reading but falter when faced with the task of comprehending and constructing knowledge from text.

Though reading difficulties in the early grades can often be attributed to specific factors—phonological deficits, for example (Adams, 1994)—an explanation for the difficulty in reading comprehension among adolescent readers is complex, because often reading comprehension difficulties are unexpected relative to earlier success. By middle school, students have, ideally, learned the bottom-up processes of word reading to facilitate the top-down work of building semantic representations of text needed for comprehension (Adams, 1994). However, decoding and fluency, while essential components for comprehension *to* occur (LaBerge & Samuels, 1974), do not ensure reading comprehension *will* occur. Basic reading skills mastered in the early grades may no longer be sufficient when the adolescent reader encounters expository text laden with complicated vocabulary, unfamiliar structures, and abstract concepts (Alvermann & Boothby, 1983; Biemiller, 2003; Graesser, Hauft-Smith, Cohen, & Pyles, 1980; Taylor, 1982).

Theoretical models of reading comprehension emphasize the role of background knowledge and inferential processes. For example, Kintsch's construction integration theory (1994) posits that the reader builds a literal representation of the text, called the textbase, from information explicitly stated, including the relationship of words and sentences to one another, and the relationship of large portions of the text to one another. The reader then must supply background knowledge to make the inferences necessary for more in-depth comprehension and build what is known as a situation model (Kintsch, 1994). The Direct and Inferential Mediation Model of reading comprehension (DIME; Cromley & Azevedo, 2007) builds on Kintsch's theory, emphasizing background knowledge and inference as important predictors of comprehension. Within this model, background knowledge facilitates the use of reading strategies; reading strategies, in turn, facilitate inference generation. Comprehension, then, is a complex interaction of factors, including what the reader brings to a text, the given purpose for reading, and the text itself (Snow, 2002).

Comprehension Development

In addition to the increased difficulty of text, shifts in instructional practice may contribute to comprehension difficulties of adolescent readers as they experience the widely-acknowledged transition from learning to read to reading to learn (Chall, 1983). Students are expected to develop domain knowledge from a text (Snow, 2002), but gleaning sophisticated levels of content knowledge from text is unlikely to happen without sustained and intentional instruction (Anderson, 1985; Shanahan & Shanahan, 2008; Snow & Biancarosa, 2004). Often by the middle grades, little explicit instruction is provided beyond generic comprehension strategies such as summarizing, questioning, or predicting (Shanahan & Shanahan, 2008). With infrequent practice reading informational text in the elementary school years (Duke & Bennett-Armistead, 2003), some adolescent readers may falter due to the convergence of newly complex text, lack of background knowledge, and limited instruction to overcome both (Dennis, Ellerbrock, & Kiefer, 2011). Addressing these factors within the confines of middle school and secondary schedules and resources can be challenging. One potential solution is integrated instruction, intended to concurrently improve students' access to expository text and the content within (Dennis, Ellerbrock, & Kiefer, 2011; Vacca, 2002).

Defining Integrated Instruction

Definitions and terms for the concept of integrated instruction vary across the literature, but commonalities exist in descriptions of its pedagogy. Generally, the concept of integrated instruction is presented as a continuum in which two disciplines become increasingly interwoven, transcending isolated skills and moving toward more abstract processes of learning (Stoddart, Pinal, Latzke, & Canaday, 2002). Integrated instruction is characterized by an inquiry-based, student-centered approach (Mathison & Freeman, 1998). Two approaches anchor each end of the continuum: interdisciplinary and integrated (see Figure 1).

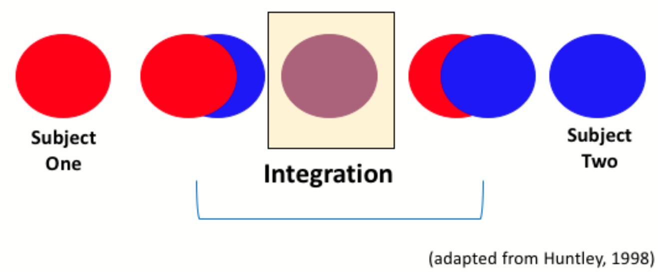

Figure 1. Models of Integrated Instruction.

Interdisciplinary instruction thematically joins two disciplines but maintains a distinct boundary between them. In other words, it is possible to observe interdisciplinary instruction and identify when instruction in one area ends and another begins. Huntley (1998) describes interdisciplinary using a "foreground/background" heuristic, in which one discipline exists in the foreground with specific content objectives to be mastered and the other in the background to establish relevance or context. Jacobs (1989) defined interdisciplinary as a way of applying the methodology and language of a one discipline to an overarching topic or theme and emphasized that the division of the school day into blocks of time per subject is not characteristic of an interdisciplinary approach. Rather, interdisciplinary instruction would make clear to students the connections among subjects.

Alternatively, integrated instruction blurs the boundaries of each discipline, making it nearly impossible to tell when instruction in one ends and another begins. Instruction is designed around abstract processes and assumes content knowledge is not a prerequisite to higher levels of thinking (Mathison & Freeman, 1998), but will instead be authentically embedded as “threads” spiraling off a broader theme (Nielson, 1989). In general, both approaches emphasize relevance—both would teach literacy relative to the learned content, drawing parallels to real-world reading and writing within the discipline. Though at the forefront of curricular conversations surrounding Common Core standards, integrated instruction is not new—it has long been proposed as a way to facilitate global thinking.

Historical Perspectives of Integrated Instruction. As early as 1894, reading in the content areas was part of research and policy agendas. In the 1920s, some philosophies of education suggested that teaching students *how* to learn was of equal importance to *what* they learned. Proponents of the progressive education and functional literacy movements of the 1930s advocated for a holistic, contextual approach to curriculum that was thought to foster the connections and knowledge necessary to be an informed citizen of any democracy (Appleby, 1998; Monaghan, 2007; Smith, 1934; Stedman & Kaestle, 1987). Pedagogy initially centered around integrating study methods, activation of prior knowledge, and metacognition (Fitzgerald & Robinson, 1989; Venezky, 1986).

In the 1940s and 1950s, research continued to explore the effectiveness of interdisciplinary approaches. For example, the work of Bloom (1956) encouraged coherence across curriculum as a way to improve understanding and make learning authentic and relevant. From 1960 forward, researchers began to consider experimentally how to situate literacy in the content areas, studying the effects of specific organizational and metacognitive strategies for learning from expository text. With multiple disciplines and methodologies in play, research and theory on integrating reading and content instruction began to diverge into two approaches, present still in both research and practice: content-area reading and disciplinary literacy.

Content Area Reading. Integrating reading instruction into the content area curriculum has been suggested as a method of improving students' reading comprehension and access to content knowledge (Anderson, 1985; Shanahan & Shanahan, 2008; Snow & Biancarosa, 2004). Content area reading instruction is based on the premise that skilled reading of informational text must be strategic (Alexander & Jetton, 2000; Fang, 2012; Spiro, 1980). The strategies of content area reading are typically applied within a direct instruction model (Roehler & Duffy, 1984) that includes explanation of the strategy's purpose, teacher modeling, guided student practice with feedback, and opportunities for independent application of the strategy. Adolescents with reading disabilities who are provided direct and explicit strategy instruction make significant gains in reading comprehension as compared to students who receive traditional instruction (Kamil et al., 2008; NRP, 2000; Swanson, 1999).

In the past 30 years, research has empirically tested the effectiveness of myriad reading strategies suited for content area reading, broadly categorized into practices students use before, during, and after reading (Duke, Lindner & Yanoff, 2016). More specifically, Carlisle and Rice (2002) suggest four categories of reading strategies. Preparatory strategies are those used before reading to help readers effectively access existing knowledge to support comprehension, such as activating background knowledge (Spires & Donley, 1998). Organizational strategies are used to help readers understand text at a macro level and may include identifying the overall structure of a text (Armbruster, Anderson, & Ostertag, 1987; Berkowitz, 1986; Taylor, 1982), identifying the main idea (Baumann, 1984; Langdon, Sjostrom, & Chou Hare, 1984; Stevens, 1988), or summarizing (Bean & Steenwyk, 1984; Rinehart, Stahl, & Erickson, 1986). These strategies can be effectively supported by the use of graphic organizers (Alvermann & Boothby, 1986; Moore & Readance, 1984; Simmons, Griffin, & Kameenui, 1988). Elaborative strategies are those used to help the reader integrate background knowledge with the text and may include question generation (Adams, Carnine, & Gersten, 1982; Davey & McBride, 1986), and making inferences (Carr, Dewitz, & Patberg, 1983; Elleman, 2017). Finally, executive strategies are intended to bring attention to the active process of reading and understanding, such as metacognition (Nelson, Watson, Ching, & Barrow, 1993). Any of these strategies could be implemented in a content area classroom; content area literacy assumes the strategy would be applied not only to the text at hand, but generalized to subsequent expository text as well.

Disciplinary Literacy. Disciplinary literacy is rooted in the assumption that learning is language-based, and each content area has unique literacy processes and strategies (Draper & Broomhead, 2010). Disciplinary literacy encourages readers to deeply engage with a text in the way a content expert would (Fang & Schleppegrell, 2008). Specialized language structures used by experts are not readily apparent to novice readers, who are unlikely to apply discipline-specific strategies without being explicitly taught to do so. For example, text structures within science and social studies are distinct; therefore, the practices necessary to comprehend each type of text are not generalizable (Cook & Mayer, 1983; Freebody & Muspratt, 2007).

While content area reading offers common strategies that apply to any expository text, disciplinary literacy capitalizes on *differences* among texts. It makes the implicit processes of creating, evaluating, and communicating knowledge within a discipline explicit to students (Hynd-Shanahan, 2013; Monte-Sano, De Le Paz, & Felton, 2014; Tang, 2016). In-depth knowledge may cumulatively improve comprehension of content-area texts if students learn to organize information conceptually and retrieve knowledge in the fluid, contextualized ways that experts do (Bransford, Brown, & Cocking, 2000; Jetton & Alexander, 2001). Proponents of disciplinary literacy would conclude that generic comprehension strategies, such as some used in content area reading, are not effective for comprehension of text that has domain-specific language and concepts (Alvermann, Rezak, Mallozzi, Boatright, & Jackson, 2011).

Though content-area reading is neatly encapsulated in reading comprehension theory, a succinct theoretical representation of disciplinary literacy is more challenging. Disciplinary literacy is rooted in several fields—not only in the disciplines themselves, but in broader theories of literacy, linguistics, and educational psychology (Hynd-Shanahan, 2013). Several lines of research have addressed the theoretical underpinnings of disciplinary literacy. Beyond the traditional situation model of one text, Goldman et al. (2016) suggest three additional levels that apply to disciplinary reading—integrated, intertext, and task. At the integrated level, readers connect the separate situation models of multiple texts. The intertext level includes the practices of determining source credibility based on the author and the context in which it was written, along with its relationship to other sources. The task level includes the reader's goals and strategies chosen for a text. Using this three-level model, readers begin by establishing a task model to determine the strategies best suited for a text, followed by applying inferential reasoning that precipitates comprehension at the integrated and intertext levels.

An additional representation of disciplinary reading is based in Gee's (2001) discourse theory, that learning to read involves the acquisition of varied "social languages" beyond one's most familiar vernacular. Disciplinary literacy, in that sense, is an ongoing, active process of immersing students in the discourse of a particular group as part of acquiring and communicating knowledge effectively (Guthrie & Alao, 1997; Hillman, 2014).

Broadly, explanations of disciplinary literacy cast a wide net in their definition of literacy, placing language at the core and deemphasizing generic strategy instruction. Practices within disciplinary literacy are in opposition to a linear content area reading strategy-first approach. Alternatively, disciplinary literacy is a reciprocal process between text and reader that operates within the discourse and norms of a discipline (Dew & Teague, 2015; Hynd-Shanahan, 2013).

Though there is not yet evidence for an effective progression to develop disciplinary literacy, some suggest providing opportunities to engage in its basic premise as early as elementary school (Bradbury, 2014). Precursory skills to full expertise in a discipline could be reasonably expected to develop by middle school, including perspective taking, reasoning skills, and facility with academic language (Duhaylongsod, Snow, Selman, & Donovan, 2015). Recommendations for how to best scaffold disciplinary literacy are emerging as the construct is more precisely defined.

Limitations of Content Area Reading and Disciplinary Literacy. Ideally, reading strategy instruction in the content area classroom is a reasonable solution to support learning from text. However, Fisher and Ivey (2005) found that despite ongoing efforts by schools, reading strategies were rarely implemented in the content areas. Explanations for minimal reading strategy instruction in the disciplines may include lack of professional development, teachers' limited desire to go beyond their area of expertise, and/or the volume of content to be covered within the constraints of a school-year calendar (Gillis, 2014; Hall, 2005; O'Brien, Stewart, & Moje, 1995; Vaughn et al., 2013).

Another debate concerns the utility of content area reading strategies for adolescent readers. Strategy instruction has extensive support for improving the reading comprehension of struggling readers (Bakken, Mastropieri, & Scruggs, 1997). However, reading comprehension literature suggests proficient readers naturally employ a range of these strategies as part of active engagement with text (Brown, 1981; Pressley & Afflerbach, 1996) and further explicit instruction in the strategy itself may not be useful for populations of already-proficient readers. Additionally, in the absence of instruction that develops the background knowledge and vocabulary necessary to comprehend complex informational texts, isolated strategies may be of little help (Fisher, Grant, & Frey, 2009).

Disciplinary literacy, though an intriguing alternative to content area reading strategy, has little empirical evidence to support its use, particularly with at-risk readers. Several studies caution that disciplinary literacy practices are unlikely to be effective if teachers do not have an in-depth understanding of their discipline beyond factual knowledge. Becoming an expert teacher of any discipline requires knowledge of not only content, but also the pedagogical practices to best deliver that content (Bransford, Brown, & Cocking, 2000). Curriculum must be designed to allow teachers the time and autonomy to identify and develop best instructional practices specific to their content area (Fang et al., 2008; Hannant & Jetnikoff, 2015).

To support comprehension for all students, content area reading and disciplinary literacy does not require an "either-or" decision. Teachers should consider the current ability of students and the level of thinking required to meet a particular goal, then choose appropriate strategies (Koedinger, Corbett & Perfetti, 2012). For example, traditional reading comprehension strategies can be embedded into discipline-specific instructional practices (Faggella-Luby, Graner, Deshler, & Drew, 2012). One program in particular, outlined in a study by Vaughn et al. (2013), bridges content-area and disciplinary approaches by implementing generalizable comprehension instruction that is particularly relevant for learning social studies content. Promoting Acceleration of Comprehension and Content Through Text (PACT; Vaughn et al., 2013), uses a content-centered approach to improve reading comprehension. Among the goals of PACT are to improve reading comprehension in ways that are both aligned with content learning and accessible to content-area teachers. The program focuses on text-centered discussion, vocabulary, knowledge acquisition, and team-based learning. Students in the intervention groups outperformed typical instruction control groups on measures of content knowledge and reading comprehension, both content-based and standardized. Using this method of instruction, the reading comprehension instruction was aligned with the content taught. Joining the approaches in this way may occur authentically as teachers scaffold learning in content area classrooms. For example, Adams and Pegg (2012) observed that content area teachers did implement strategies when in alignment with their instructional practices and goals. Similarly, Heller and

Greenleaf (2007) suggested that content area teachers should not be responsible for teaching basic reading instruction, but rather, must identify the literacy skills essential to their discipline and use them in support of content learning.

However, it still remains that for at-risk readers, direct, explicit instruction and intensive interventions are effective and necessary (Kamil et al., 2008). General education teachers should be aware that students with disabilities require support if they are to be successful in learning content from text (Denton, Vaughn, & Fletcher, 2003). Ongoing dialogue among literacy experts and content area experts is needed to determine which strategies are most effectively applied in the content area classroom and which are best left to develop under the guidance of specialized literacy professionals (Brozo, Moorman, Meyer, & Stewart, 2013). Schools should rely upon the expertise of content and reading teachers in sensible ways rather than adopting curricular goals that force dichotomies for the sake of integrating instruction (Dickinson & Young, 1998).

Present Studies

The first study uses an experimental design to evaluate the effects of an inferential strategy and content knowledge intervention on reading comprehension and content learning. Participants included 94 fifth-grade students of average to above-average reading ability in a suburban school. After a ten-hour intervention that simultaneously taught reading strategies and content knowledge to support inference generation, both inferential and content knowledge intervention groups performed better on a researcher-created measure of reading comprehension when compared to a business-as-usual control, though not on a standardized measure of reading comprehension. There were no statistically significant differences between the content knowledge and inferential intervention groups on a measure of content learned, indicating either method of strategy instruction was effective for knowledge acquisition.

The second study explores building content knowledge and reading comprehension simultaneously through the practice of integrated instruction in a meta-analytical review of studies that used an integrated literacy approach to science instruction. A comprehensive search of the literature was conducted, and studies that met the criteria for inclusion were coded identify design, participant, and intervention characteristics that may be associated with effect size. The final analysis included 36 effect sizes for science outcomes and 14 effect sizes for literacy outcomes, analyzed separately. Results show an overall weighted mean effect of 1.04 for science outcomes and .245 for literacy outcomes, evidence that the practice of integrating science and literacy instruction is effective.

Both studies assume reading comprehension to be the product of a reader-created situation model (Kintsch, 1998), in which the reader supplements explicitly stated information with his or her own knowledge to build a meaningful representation of the text. The research presented in this dissertation investigates text-based approaches to building knowledge and the resulting effect on both reading comprehension and content learning.

CHAPTER II

STUDY ONE

Introduction

Though a convergence of research has clearly outlined best practices in early reading instruction (Adams, 1994; National Reading Panel, 2000), comprehension instruction at the middle and secondary grades remains less well-defined. The challenge of supporting adolescent readers is evident in both national and international data—the 2017 National Assessment of Educational Progress (NAEP; National Center for Education Statistics, 2017) reported that only 35% of eighth-grade students were able to comprehend grade-level text, and likewise, the Programme for International Assessment (PISA; OECD, 2016) reported the average Reading Literacy score of American 15-year-olds as lower than peers in 14 other countries.

Conjectures about the causes of adolescent reading comprehension difficulties vary, but generally include increased demands for learning through text. The well-known shift from learning to read to reading to learn that occurs around the fourth grade (Chall, 1983) may result in poor comprehension as students are exposed to text with demanding vocabulary and complex structures (Alvermann & Boothby, 1983). One explanation in particular, and the basis of this study, is that students may falter as a result of limited background knowledge to make inferences necessary for comprehension (Cromley & Azevedo, 2007; Kintsch & Rawson, 2005; Oakhill, 1984). Research has found comprehension difficulties in adequate word decoders can be explained by the inability to make inferences (Anderson & Pearson, 1984; Cain, Oakhill, Barnes, & Bryant, 2001). A meta-analysis of inference studies found that on measures of comprehension, instruction in inference was associated with moderate to large effects for inferential understanding and literal comprehension of text (Elleman, 2017).

The Role of Inference in Reading Comprehension

Authors make assumptions that readers will supply the necessary background knowledge and generate the inferences needed for comprehension; texts are not fully explicit (Roe, 1987). In this way, inferences are essential to building a representation of text, both at the microstructure level among words and sentences, and the macrostructure level among sections of a text (Kintsch & Rawson, 2005). According to Kintsch (1998), a reader is actively building a situation model of the text by considering the relationship of words, clauses, and sentences (sometimes referred to as local coherence) and the relationship of larger portions of the text to one another (global coherence). Both levels combine to form the *textbase*, a literal representation of the text's meaning. Using the textbase, a reader may be able to summarize or retell the basic propositions of a text. However, for deeper comprehension, the reader must then incorporate his or her background knowledge and use inferential reasoning (Kintsch, 1994; Kintsch & Rawson, 2005; van den Broek, 2010). The resulting representation, known as the *situation model*, is built upon this series of inferences.

In general, research has identified three broad categories of inferences used in building this situation model. *Bridging inferences* connect propositions between adjacent sentences or within sentences (Singer & Remillard, 2004). *Elaborative inferences* are made when the reader connects his or her background knowledge with the information presented in the text to draw a conclusion

(Whitney, 1987). *Text-based inferences* occur when the reader identifies specific clues in the text that assist in constructing the inference (Winne, Graham, & Prock, 1993).

Several researchers explicitly taught students to make bridging and elaborative inferences and found students improved in answering inferential questions after reading a text. Carr, Dewitz, and Patberg (1983) used a cloze procedure that prompted students to supply their own background knowledge and make inferences. Fifth and sixth grade students in the intervention group outperformed students in a typical instruction setting. McNamara, O'Reilly, Best, and Ozuru (2006) tested an interactive strategy training program that taught students to generate explanations of a passage read, make bridging inferences by linking a sentence to material previously stated in the text, and to make elaborative inferences by connecting background knowledge to the material read. Students in the intervention group improved reading comprehension and strategy use. Hansen and Pearson (1983) asked fourth-grade readers to make predictions before reading and then connect their own experiences to the text while reading for better understanding; poor readers benefitted significantly from the inference instruction. Davey and McBride (1986) taught inference through question generation and found that deeper processing of text at the macrostructure level enhanced factual recall, suggesting that training in inference generation may incidentally improve literal comprehension.

Instruction in text-based inference generation has been shown to be effective for less-skilled readers in particular. Yuill and Joscelyne (1988) had students identify what role each word in a sentence played and what information it provided. Students receiving the intervention outperformed students who received typical comprehension instruction, and less-skilled readers benefitted more than skilled readers as measured by a standardized reading comprehension assessment. A 1993 study by Winne, Graham, and Prock used a text-based strategy in which students were prompted to underline the part of the story that helped them answer an inferential question. Students taught to infer using the textual clues answered more inferential questions correctly than students in a control group. Barth and Elleman (2017) provided an inference strategy intervention to students with poor reading comprehension that emphasized the use of text clues and found positive effects on measures of reading comprehension and knowledge learned from the text.

Background Knowledge

These studies provide evidence for using direct explanation, modeling, and feedback to teach students how a variety of inference types are made. However, some researchers suggest strategy instruction, though demonstrated to be important for poor readers, is a one-time boost—for example, Willingham (2017) writes that even with effective initial instruction in strategy use, comprehension may break down if readers still lack the knowledge necessary to connect ideas in a text. In addition to direct instruction in inference generation, then, remains the task of developing the background knowledge students need to make appropriate elaborative inferences. Inference generation is highly dependent on a reader's background knowledge (Kendeou, van Den Broek, Helder, & Karlsson, 2014; Kintsch & Kintsch, 2005; McNamara & Kendeou, 2017) and the ability to use the background knowledge to fill in information not explicitly stated in a text (Kendeou & O'Brien, 2015; McNamara & Magliano, 2009).

The Direct and Inferential Mediation Model of reading comprehension (DIME) was developed by Cromley and Azevedo (2007) and takes into account factors typically considered contributors to reading comprehension in other theories, such as word reading and vocabulary. However, it also hypothesizes that background knowledge, strategy use, and inference are predictors of comprehension. Under the DIME model, background knowledge is necessary for students to apply strategies such as summarizing or self-questioning. Inferences, then, are made as a result of such strategies being applied. The full DIME model in the 2007 study explained 66% of variance in reading comprehension, and specifically found that vocabulary and background knowledge made the largest contribution to reading comprehension. Similar results were found in other studies, with some variation in the weight of the predictors. For example, a 2010 replication by Cromley, Snyder-Hogan, and Luciw-Dubas found that background knowledge explained more variance than vocabulary. Ahmed et al. (2016) found that vocabulary and background knowledge were similar predictors of comprehension, but in this study the effect of inference making increased. A partial replication of the 2007 Cromley and Azevedo study by Oslund et al. (2016) found the contributions of background knowledge, vocabulary, and inference making were nearly identical. Overall, however, the consistency of results across studies speaks to the influence these subskills contribute to reading comprehension.

Generative, schema, and constructivist theories of reading comprehension all address the role existing knowledge plays as readers build a coherent representation of text in long-term memory (Doctorow, Wittrock, & Marks, 1978; Spiro, 1980). As early as 1932, the work of Bartlett suggested that comprehension was an effort to make connections between given and existing knowledge, a theme still prevalent in reading comprehension research. For example, Kendeou, Walsh, Smith, and O'Brien's (2014) Knowledge Revision Components framework for comprehension is based on the process readers follow as they integrate current knowledge to build a representation of a text and continually update it with new knowledge learned. Other studies have demonstrated knowledge of a subject to facilitate comprehension, even among typically poor readers (Compton, Miller, Gilbert, & Steacy, 2013; Miller & Keenan, 2011).

Purpose of the Study

Although Elleman (2017) recommended that interventions simultaneously build in-depth background knowledge *and* explicitly teach inference generation, no studies have considered whether instruction focused on building background knowledge or studies focused on teaching general inference skills are best for comprehension development. The present study seeks to answer several questions relative to narrative and expository text and the effectiveness of an elaborative and text-based inference intervention that concurrently builds knowledge to improve reading comprehension. The studies reviewed thus far have determined the effectiveness of direct inference strategy instruction using similar methods. In this study, we taught students to apply multiple cognitive inference strategies while using expository text to provide the knowledge necessary to more effectively make elaborative inferences in the related narrative text.

Research Questions

1) What is the impact of inferential strategy instruction and content knowledge instruction compared to a business-as-usual control group on general reading comprehension (i.e., Gates MacGinitie)? If there are differences among groups, which condition was better for improving general reading comprehension?, 2) What is the impact of inferential strategy instruction and content knowledge instruction compared to a business-as-usual control group on domain-specific reading comprehension (i.e., Egyptian Comprehension Assessment)? If there are differences among groups, which condition was better for improving domain-specific reading comprehension?, and 3) What is the impact of inferential strategy instruction and content knowledge instruction compared to a business-as-usual control group on content knowledge acquisition (i.e., Egyptian Content Knowledge)? If there are differences among groups, which condition was better for improving content knowledge acquisition?

Method

Participants

After obtaining permission from the school and the district, 94 fifth-grade students were recruited. This elementary school averages 750 students across grades K-5; around 27% of those students typically qualify for free or reduced lunch. Of the entire student body, around 22% of students enrolled are of ethnic categories other than white (see Table 1 for demographic information specific to the 5th grade participants). Students took home a consent form for parental permission to participate in the study. Students who then returned the parental consent form were read the student assent asking for their permission to participate in the study. After receiving parental permission and the children's assents, we randomly assigned participants to one of three conditions: 1) Reading Detectives Inference Instruction, 2) Explorers Content Knowledge Instruction, or 3) a business-as-usual control group.

Table 1

Demographic Information for Fifth-Grade Participants

	n	%
Female	56	60.0
Students with IEP	5	5.3
Ethnicity		
White	81	86.2
African-American	3	3.19
Hispanic	7	7.45
Other	3	3.19

Conditions

Reading Detectives Inference Condition (RDI). Based on a meta-analysis of inference training studies, small group instruction was found to have a positive relationship with effect size (Elleman, 2017). In addition, most studies included in the meta-analysis showed positive results in a short amount of time (Elleman, 2017). Therefore, trained doctoral students taught small groups of five children for ten days, one hour per session, providing a total of 10 hours of inference instruction. Students in the inference condition were taught to be "Reading Detectives," using text clues and elaborative strategies to better understand text. In addition, they practiced answering and generating inferential questions. Students learned to apply inference strategies using engaging, grade-level expository and narrative text with an ancient Egypt theme (e.g., the book *Tut! Tut!* by Jon Scieszka, with a 700 Lexile measure, and a related field guide, *Mummies and Pyramids* by Mary Pope Osborne, a 650 Lexile measure). Students read the text with the group, discussed how to apply the inference strategies, and posed and answered inferential questions.

The Reading Detectives lessons followed an evidence-based model of comprehension instruction that includes: a) explicit description of the strategy and its purpose, b) teacher modeling of the strategy, c) guided practice with a gradual release of responsibility from teacher to student (Pearson & Gallagher, 1983), and e) independent application of the strategy (Duke & Pearson, 2008). Introductory lessons taught students what an inference is and how making inferences is similar to being a detective. Students learned specific patterns and clues authors use that can help in making inferences, such as noticing repeating information or thinking about a character's motive. Students practiced finding text clues in short passages and learned to identify inferential questions.

Next, students began reading informational text to practice the strategies presented in the two initial lessons. Students developed background knowledge of ancient Egypt and practiced applying inferential reasoning. Each lesson began with direct instruction of the vocabulary students would encounter in that day's reading. Chapters were read aloud to eliminate confounding difficulties with decoding. Students learned to make relevant connections to prior knowledge, looked for clues in the text, generated questions, and drew conclusions about big ideas. After reading, students practiced identifying question types and applying strategies to answer the questions. The last five minutes of each session was used for students to discuss the day's reading. See Appendix A for a sample lesson from the RDI condition. Following five days of reading the informational text, students read a fictional story set in ancient Egypt, continuing to practice the strategies introduced through the informational text.

Reading Explorer Content Knowledge Condition (REC). Students in this condition were taught to engage in close reading of the content and read the same materials as the RDI Condition. Introductory lessons taught students to be "Reading Explorers" by finding and learning new information in text. Students were prompted to look back to the text for answers, write down three facts from each section read (particularly key people, places, or objects), and make a list of key events from the chapter. After each chapter was read, students answered literal-level questions geared toward the content knowledge of the text. See Appendix B for a sample lesson from the REC condition.

Control Condition. The curriculum used with the control group was representative of typical classroom instruction. Portions of units designed for educators in the state of Tennessee were used to guide students in learning to critically read informational text, answer text-dependent questions, and analyze multiple perspectives in text to develop an opinion essay. Each lesson included activation of background knowledge, teacher modeling, independent reading, group discussion, and written response. Specifically, the lessons centered around the benefits and costs of space exploration.

Fidelity of Treatment

All teaching sessions were provided by trained doctoral students who demonstrated competence for providing instruction before working with students. Tutors were randomly assigned to either the Reading Detectives Inference or Reading Explorers Content Knowledge groups to minimize possible diffusion effects. All 150 teaching sessions were recorded and 25 percent of them randomly selected to review for fidelity (see Appendix D for sample fidelity checklist). Fidelity was defined as inclusion of all necessary components of the condition, appropriate teacher feedback to students, and absence of treatment diffusion (for example, asking inferential questions in the REC condition). For the inference condition, fidelity was 100%. For the knowledge condition, fidelity was rated at 90% due to an occasional inferential question being included in the post-reading discussion.

Research Design and Measures

This study used a pretest-posttest control group experimental design with individual random assignment. Although randomization is necessary for establishing group equivalence, it is not always sufficient, especially with small samples (Gall, Borg, & Gall, 1996). Therefore, to control for factors that may have affected group equivalence, pretests were administered to assess various cognitive and academic constructs, including academic knowledge using a subtest from the Woodcock-Johnson Psychoeducational Battery (WJ-III; Woodcock, McGrew, & Mather, 2001), verbal and matrix reasoning (WASI; The Psychological Corporation, 1999) and word-reading efficiency (TOWRE-2). The battery of individually administered tests required about an hour per student.

Group-administered pretest measures included the Gates MacGinitie Reading Test and two researcher-designed measures. The researcher-designed measures assessed the literal and inferential understanding of the texts used in the intervention and included multiple questions using different item formats (e.g., multiple choice, cloze, and open-ended) for both literal and inference questions. The items and questions were reviewed by reading and content experts for content validity. Group administered measures required about 2.5 hours for students to complete both pre and post-tests. Testing was conducted by trained doctoral students who demonstrated competence (100% fidelity) in administering each measure before meeting with students. A description for each of the measures follows.

Pretests

Woodcock-Johnson III General Academic Knowledge Subtest. Students' background knowledge in science, social studies, and the humanities was assessed with Woodcock-Johnson Psychoeducational Battery III: Academic Knowledge (Woodcock, McGrew, & Mather, 2001). Split-half reliability exceeded .92.

Tests of Word Reading Efficiency (TOWRE-2). The TOWRE-2 consists of two subtests that measure a student's ability to read sight words and phonemically regular nonwords with accuracy and fluency. In each subtest, students had 45 seconds to read lists of words. Alternate forms reliability for both subtests were above .90.

Weschler Abbreviated Scale of Intelligence (WASI). The verbal reasoning and matrix reasoning subtests of the WASI (The Psychological Corporation, 1999) were administered to determine overall cognitive ability of students. According to Zhu (1999), the correlation with the Wechsler Intelligence Scale for Children (WISC) was .89 for the verbal reasoning subtest and .87 for the matrix reasoning subtest.

Outcome Measures

Gates-MacGinitie Reading Test (GMRT). The GMRT (MacGinitie et al., 2000) is a reading comprehension test with two subtests: vocabulary and comprehension. For the vocabulary subtest, students chose the correct synonym or phrase for a given word. The comprehension subtest assessed silent reading comprehension with a series of increasingly difficult passages, each followed by multiple-choice questions. The test-retest reliability exceeded .90. Students were given 55 mintues to complete the test.

Ancient Egypt Content Knowledge Assessment. This test is a researcher-designed measure with 20 items that assess the vocabulary and content learned about ancient Egypt. The format of the test is a mixture of cloze items, multiple choice, and open-ended questions, and took ten minutes to complete (see Appendix E). Internal consistency of the measure from a pilot study with elementary age students was .89.

Ancient Egypt Comprehension Assessment. This test is a researcher-designed measure that required approximately 30 minutes to complete, with 28 items across three passages about Ancient Egypt. The passages contained content about Egypt not covered in the intervention. The measure includes inferential and literal questions. The format of the items was a mixture of cloze, multiple choice, and open-ended questions (see Appendix F). Internal consistency of this measure from a pilot study with elementary age students was .84.

Results

Students' existing word reading ability, general academic knowledge, and cognitive ability are factors that could contribute to the outcomes measured in this study. Therefore, an ANOVA was used to ensure group equivalency on measures of word reading efficiency (TOWRE-2; Torgesen, Wagner, & Rashotte, 1999), general academic knowledge (WJ-III; Woodcock, McGrew, & Mather, 2001), and cognitive ability (WASI; The Psychological Corporation, 1999). Datasets from each of the measures for each group met assumptions for normality and homogeneity of variance, assessed by both visually inspecting plots for outliers and examining results of Shapiro-Wilks and Levene's tests. After checking all assumptions and proceeding with the analysis, ANOVA showed no statistically significant difference among groups for the pretest measures (see Table 2).

Table 2
Group Means and Standard Deviations for Pretest Measures

	Group 1 Reading Detectives (*N* = 32)		**Group 2** Reading Explorers (*N* = 32)		**Group 3** Typical Instruction (*N* = 32)		
Measure	***M***	***SD***	***M***	***SD***	***M***	***SD***	**ANOVA**
WASI	108.94	15.00	107.26	14.67	107.26	13.70	$F(2,91) = 0.14$, $p = .87$
TOWRE	184.03	22.50	181.10	27.92	184.68	16.85	$F(2,91) = 0.22$, $p = .81$
WJ-AK	99.84	13.81	99.68	14.63	99.97	10.39	$F(2,91) = 0$, $p = .99$

Note. WASI = Weschler Abbreviated Scale of Intelligence Standard Score; TOWRE = Test of Word Reading Efficiency Standard Score; WJ-AK = Woodcock Johnson Test of Academic Knowledge Standard Score

Next, three separate ANCOVA analyses were conducted for outcome measures given at pre and posttest, using the pretest score as a covariate, to determine if a statistically significant difference among groups existed after controlling for pretest values. First, analyses on both a standardized and researcher-created comprehension measure were conducted to determine if one of the conditions was more effective in improving reading comprehension. For the Gates MacGinitie Reading Comprehension measure, no significant difference was found among the three groups, $F(2, 74) = 0.615$, $p = .544$. On the researcher-created measure of comprehension (Ancient Egypt Comprehension Assessment), a significant difference was found among the three groups when controlling for pretest scores, $F(2, 77) = 6.72$, $p = .002$. Pairwise comparisons using the Bonferroni method indicated differences between the REC and Control group ($p = .002$) and between the RDI and Control group ($p = .024$), however, no statistically significant difference was found between the two treatment groups, RDI and REC ($p = .147$). See Table 3 for group means and standard deviations by outcome measure.

The third analysis addressed the content knowledge learned by looking for differences among the three groups. For the measure of Egyptian Content Knowledge, a significant difference was found among the three groups when controlling for pretest scores, $F(2,86) = 68.71$, $p < .01$. Pairwise comparisons using the Bonferroni method indicated differences between the REC and Control group ($p < .01$) and between the RDI and Control group ($p < .01$); however, no statistically significant difference was found between the two treatment groups, RDI and REC ($p = .091$). The Benjamini Hochberg method (1995) was applied to control for false discovery rates when making multiple comparisons. After adjusting the critical p value, all comparisons remained significant except the differences among groups on the Gates MacGinitie reading comprehension measure.

Table 3
Descriptive Statistics by Condition

	Group 1 Reading Detectives (*N* = 32)				**Group 2** Reading Explorers (*N* = 32)				**Group 3** Typical Instruction (*N* = 32)			
	Pretest		**Posttest**		**Pretest**		**Posttest**		**Pretest**		**Posttest**	
Measure	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***	***M***	***SD***
GMRT	35.46	7.92	37.58	7.42	33.38	11.11	36.50	9.99	35.32	6.18	38.00	4.34
Content	6.3	3.72	14.87	4.43	6.8	4.5	16.71	4.63	7.2	3.9	7.17	3.41
Comp	19.22	5.37	18.76	5.48	18.88	6.65	20.12	6.23	19.87	5.01	17.44	6.05

Note. GMRT = Gates MacGinitie Reading Test Standard Score; Content = Ancient Egypt Content Knowledge Assessment; Comp = Ancient Egypt Comprehension Assessment

Effect sizes were calculated as Cohen's *d*, a representation of the difference between the treatment and control group means divided by the pooled standard deviation of the means. Effect sizes were then adjusted using Hedge's *g* to control for the small sample size and the tendency of *d* to overestimate the absolute value of β (Hedges, 1981). See Table 4 for effect size data.

Table 4
Effect Sizes

	RDI v. Control	**REC v. Control**	**RDI v. REC**
	g	*g*	*g*
Content	1.98	2.32	-0.32
Comp	0.29	0.39	-0.12
GMRT	-0.17	-0.21	0.06

Note. Content = Egyptian Content Knowledge Assessment; Comp = Egyptian Comprehension Assessment; GMRT = Gates MacGinitie Reading Test; * indicates statistically significant from zero at the *p* = .05 level.

Discussion

Inference strategy instruction did improve comprehension on a researcher-created measure, with an effect size (*g* = 0.29) of substantive importance (What Works Clearinghouse, 2017). However, gains in comprehension did not transfer to a standardized test of reading comprehension (*g* = -0.17). Consistent with other reading comprehension studies, standardized measures are less sensitive to change and typically result in lower scores than measures more closely aligned to the intervention (Scammacca et al., 2007).

Though there were differences on the researcher-created measure between the treatment and control groups, no difference was found between the RDI and REC treatment groups. Students receiving content knowledge instruction fared as well on the comprehension measure as those receiving inferential strategy instruction. In fact, the effect size (*g* = -0.12) indicates the REC group may have had a slight advantage over the RDI group. There are several plausible explanations for this finding. First, the sample of students in this study were average to above-average readers. Proficient readers use strategies fluidly and with greater automaticity (Carlisle & Rice, 2002). It could be that, consistent with other studies, the *type* of strategy taught was of less significance than the fact students had an increased metacognitive awareness of strategy use and a heightened focus on the text (Carnine & Kinder, 1985; Rosenshine & Meister, 1994). Good readers make inferences automatically when text is coherent and background knowledge is sufficient to fill in gaps (McKeown, Beck, Sinatra, & Loxterman, 1992) so specific strategy instruction in making inferences may not have been necessary to improve reading comprehension for this sample of students.

A second explanation is that having deep background knowledge of the subject mattered. The Egyptian comprehension assessment passages, though only tangentially related to topics covered in the intervention, were still within the same domain of knowledge. The fact that both intervention groups performed better than the control group, who had no exposure to the Egypt content, suggests that perhaps some background knowledge helped in students' approach to the post-assessment. This builds upon other studies that have shown general knowledge of a subject to facilitate comprehension (Barnes, Dennis, & Haefele-Kalvaitis, 1996; Recht & Leslie, 1988). Additionally, this deep background knowledge may have precipitated improved comprehension via less disruption as the reader worked to create a situation model of the text. The Knowledge Revision Components framework (KReC) developed by Kendeou, Walsh, Smith, and O'Brien (2014) proposed that comprehension involves a reader continuously updating and revising his or her current knowledge base as new knowledge in a text unfolds. Under this framework, new knowledge that is in conflict with previously activated knowledge causes a disruption in comprehension to be resolved; however, if new knowledge is built through causal explanations and a number of exposures, the preexisting knowledge is less likely to cause glitches in comprehension when reactivated. Relative to this study, students had in-depth knowledge of the topic after the intervention, and therefore, it could be that when presented with a closely related passage that did not refute this knowledge, little work was required to integrate existing knowledge with the text to create a representation of its meaning.

The third research question was included to determine if strategy instruction, and which type, benefitted content acquisition. Not surprisingly, students in both the inference strategy group (*g* = 1.98) and content knowledge group (*g* = 2.32) who were exposed to the Egypt content far outperformed control group students who had no exposure to the content. However, the fact that no statistically significant differences were found between the REC and RDI conditions suggests both groups learned the content equally well regardless of the reading strategy learned. This study corroborates evidence from several other studies that have shown effective content learning can take place with strategy instruction to improve comprehension (Elleman, 2017; Romance & Vitale, 2001; Williams et al., 2009); in other words, though the focus of an intervention may be reading strategy instruction, content can be learned simultaneously.

Limitations of Current Study and Suggestions for Future Research

Some limitations were present in the design of the study—for example, this study was conducted with average to above-average readers and it may be that the instruction was not needed for these students. Additionally, the sample size was relatively small to fully extrapolate findings. The duration of the intervention may have influenced the results as well. Though comprehension strategies can be learned in a short amount of time (Willingham, 2017), this intervention required students to learn both strategy and content. Future research might consider the optimal length of an intervention when content and strategy instruction are combined. The measures selected for the study may not have been sensitive to changes in inferential processes. For example, a study by Barth and Elleman (2017) provided a similar inference strategy intervention and found significant effects on the WIAT-III standardized reading comprehension assessment.

The purpose of this study was to determine if simultaneously building knowledge and providing inference strategy instruction resulted in improved comprehension and content acquisition. Results show that, for this group of readers, both near-transfer comprehension and content learning improved via one of the two treatment conditions, inferential or content knowledge instruction. This study used a historical topic, ancient Egypt; future studies might consider the level of comprehension improvement or content learning using a combination of narrative and expository science text or using texts of varied structure and coherence. Next steps might also be to determine what, if any, intervention might both build content knowledge and effectively transfer to a standardized measure of reading comprehension for a range of reader types.

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Appendices

Appendix A

Sample Reading Detective Condition Lesson

Reading Detectives Lesson 5

Day 5: *Mummies & Pyramids,* Chapters 6-9, pages 73-106

Lesson Overview
Before Reading
During Reading
After Reading

Lesson Sequence

Warm-up	**5 minutes**
Vocabulary	**5 minutes**
Read with Strategies	**15 minutes**
Review Question Types	**10 minutes**
Answer Questions	**10 minutes**

Overview

Warm-up. Have students read bell ringer mystery (The Case of the Hungry Clown) silently. After a couple of minutes, ask students "Do you know?" Ask what clues they used to answer the question.

Review and Vocabulary. Using teacher script on the next page, quickly review the four strategies detectives use. Remind students they will see words they may not know in the text they are reading today, and it is always OK to stop and ask to clarify a word. Ask students to follow along in their folder as you read aloud the list of words.

Read with Strategies. Have students turn to chapter six in *Mummies and Pyramids.* Read aloud as they follow along, and follow the teacher guidelines on the following pages to stop for vocabulary clarification, important clues, connections, and detective's decisions (evidence).

Review Question Types. Follow the teacher script to review the three types of questions students will encounter. Try two questions together as a group; allow students to finish the rest on their own and then discuss answers.

Reading Detectives Lesson 5

Lesson Overview
Before Reading
During Reading
After Reading

Teacher Script

Teacher: **Today we will be reading more from our non-fiction text, *Mummies & Pyramids*. We will keep practicing using our strategies. Let's review quickly before we begin. What is the first strategy good reading detectives use?**

Students: Stop and clarify.

Teacher: **Good. If we come across confusing words or ideas, we will stop to clarify them. What is the second strategy?**

Students: Look for clues.

Teacher: **Excellent. We will look for clues the author gives us. What else?**

Students: Make connections.

Teacher: **Yes, we can make two types of connections to help us with an inference. Does anyone remember them?**

Students: Text connections (find clues in the text) and outside connections (use our own knowledge).

Teacher: **Good. Both of those connections can help us make an inference when the story doesn't directly tell us something. What was the fourth strategy?**

Students: Providing evidence.

Teacher: **Great! When we read, we will weigh all our evidence and make decisions about what is the most important information. To begin, I'd like to read through a list of words we will see in today's reading that we may need to clarify. Please follow along in your notebook as I read the words.**

The words are: mastabas, burial chamber, architect, step pyramid, sphinx, shabtis, and tomb robbers. Follow along as I start reading on page 73.

Reading Detectives — Lesson 5

Lesson Overview
Before Reading
During Reading
After Reading

Clarifying

At each vocabulary word, stop and ask:

- *Does anyone see words that need to be clarified?*
- If no answer, provide word. *I think ____ is an important word to understand this part.*
- *How can we figure out what ____ means?*
- *Yes, we can be detectives and find clue words. What clues help us know what ____ means?*
- *Yes, it means ____* (or *close, it means ____*).

Page	Word	Clue Words
73	mastabas	tombs, mud bricks, flat roofs, slanted sides
73	burial chamber	mummy, buried beneath, room
75	architect	pyramid, created
76	step pyramid	set of steps, going to sky
83	sphinx	make-believe creature, body of lion, head of hawk, ram or person
86	shabtis	statues, servants
87	tomb robbers	treasures, dishonest, stolen

Connections

Students can volunteer text or outside connections during reading. If students do not, at stopping points:

Does anyone see any connections with anything we've read before?

Students may offer outside connections that are interesting, but not closely related to the text (for example, "I saw a movie about pyramids, or I read a book once about King Tut.") Remind students to make connections that help them make a specific inference about the text. An example reminder might be:

That's really interesting and it's great you have lots of background knowledge about what we're reading. For connections, let's think about things that help us make an inference. Tell me what inference you can make about something we just read by using your connection.

Page 79
"The barge that led Khufu's funeral procession" connects to previous chapter

Page 81
Farmers build the pyramids because they believe it will get them to the Next Life.

Page 85
"They wanted the dead to look their best in the Next Life." Connects to chapter 2, page 30.

Page 87
Statues acting as a home for the ba and ka – relates to Chapter 3, pages 43-44.

Page 88
Robbers taking amulets from the mummy's linen, reference to Chapter 4, page 62.

Page 93
Pyramids telling robbers where to look for treasure, relates to Chapter 6.

Reading Detectives Lesson 5

Finding Clues

Students should be encouraged to raise their hands when they hear an important clue to write down. If students suggest a good clue, acknowledge them and write it down. If students do not suggest clues, at stopping points: *Does anyone notice a clue (something the author has repeated or spent a lot of time with) that we could write down?* If no answer, *I noticed the author spent a lot of time on* _______. Or *I noticed the author repeated* _______.	**Page 75-76:** The first pyramid was made by Imhotep by building mastabas on top of mastabas. **Page 77-78:** The Pyramids of Giza are smooth-sided and built more than 4,500 years ago. **Page 80-81:** Pyramids were built by farmers during the flood season. **Page 83:** The Great Sphinx is the largest statue from ancient times still standing. **Page 85:** Egyptians wanted to be happy and comfortable in the next life. **Page 87-89:** Tomb robbers invaded many tombs. **Page 94-95:** Secret tombs were built in the valley of the kings to protect them from tomb robbers. **Page 96-100:** Howard Carter finally found King Tutankhamen's tomb.

Providing Evidence

Prompt students to weigh evidence at the places listed to the right. *Do we have enough evidence to say what's most important about this section we just read?* Students may suggest evidence; if not, use the questions listed as a starting point. Encourage students to use the words "because" or "so" to answer the question. Asking "how do you know" may seem repetitive, but helps the students verbalize the exact evidence from the text that helps them make the decision.	**Page 76:** *Why was the first pyramid built?* The first pyramid was built **because** King Zoser wanted the most wonderful burial place ever. *How do you know?* **Page 85:** *Why did the ancient Egyptians include so many things in their tombs?* Ancient Egyptians included so many things in their tombs **because** they believed they could take these things to the Next Life. *How do you know?* **Page 93:** *Why did ancient Egyptians quit burying their dead in pyramids?* Ancient Egyptians quit burying their dead in pyramids in order to protect their pharaoh, **so** tomb robbers wouldn't find the tombs and treasures. *How do you know?*

Reading Detectives Lesson 5

Lesson Overview
Before Reading
During Reading
After Reading

Teacher Script

Teacher: Great job being reading detectives today! Now we're going to answer questions about the text we just read. Does anyone remember the three types of questions?

Students: Main idea, vocabulary, and inference.

Teacher: Good. Let's try two questions together then you can try the rest on your own. Look at question one, please.

QUESTION ONE: Why would the ba and ka have no place to go if the mummy was destroyed? (page 45, chapter 3; inference question)

Teacher: This is an inference question. How can we answer inference questions?

Students: Use clues from the text or our outside knowledge.

Teacher: Yes. Let's look at page 45 and see if we can find any clues from the text to help us answer this one.

Students: It says the body was the home for the ba and ka.

Teacher: Great job using clues. Let's look at question two.

QUESTION TWO: The earliest ancient Egyptians wouldn't have been buried in a pyramid. Instead, they would have been buried below a _______. (page 73, vocabulary question).

Teacher: This is a vocabulary question because it's asking about a specific word. Remember, if we don't know what a word means, we should look in the text for clues. Let's look on page 73. Does anyone see any clues?

Students: It talks about mummies being place beneath a mastaba.

Teacher: Good. Try the rest and we'll talk about the answers in a minute.

Go over answers to remaining questions when students finish.

Lesson Overview
Before Reading
During Reading
After Reading

QUESTION THREE: Only wealthy people or royalty had pyramids because ____________. (page 43; inference question)

a) They could afford to pay the farmers.
b) They were the only ones allowed in the Next Life.
c) They were thought to be the most sacred.
d) They owned the most land.

Answer: (b)

QUESTION FOUR: The majority of the pyramids were built in the flood season because. . . (page 81, inference question)

Answer: That is when farmers were free to work.

QUESTION FIVE: Tomb robbers were said to be committing a crime against the gods because tombs were __________ (page 89; inference question).

a) sacred
b) full of treasures
c) for the dead only
d) used for prayer

Answer: (a)

QUESTION SIX: Why did pyramids tell tomb robbers exactly where to look for treasure? (page 93; inference question with connection to page 74)

Answer: The burial chamber is directly below the pyramid.

Optional: If time permits, start a five-minute discussion about the day's reading.

Use the discussion starters:

Something I noticed in the story today. . .
I think the best part of the story today was. . .

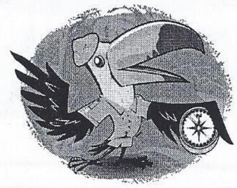
Introduce the discussion starters and then allow students to discuss. Redirect or restate discussion starters if needed.

Appendix B

Sample Reading Explorers Condition Lesson

TEACHER'S COPY – Explorers (Literal)

LESSON 6: *Mummies & Pyramids, Ch. 3-5, pgs. 41-71*



My Explorer's Notebook

*****Bell Ringer: Explorer's Story***

1. __Vocabulary__ (15 minutes)

Vocabulary Word	Synonym or Definition
Sacred p. 42	Having some religious purpose
Next Life p.43	where people went after they died
Ka p. 43	what made the person alive
Ba p. 44	what made the person different from anyone else
Decay p. 55	when the skin, hair, muscles, and other parts of the body start to rot away.
Mummy p. 55	A dead body that has been protected from decay
Jackal p. 56	a kind of wild dog that lives in Asia and North Africa
Resin p. 58	The sticky stuff that comes from trees or plants
Amulets p. 62	Magic charms wrapped in the mummy's linen strips
Scarab p. 62	beetle
Funeral procession p. 65	Walk to the tomb
Mourn p. 66	To show sadness

2. __Explorer's Notes__ - List the people, places, objects, and facts here. (15 minutes) Students should be encouraged to write down any important fact they feel is important to record. Students should be encouraged to write at least three facts from each section. Praise students for finding interesting facts, key people, places and objects.

- Egyptian gods and goddesses were often half-human and half-animal.
- Temples were where ancient Egyptians worshipped.
- Priests took care of the sacred statues of the gods and goddesses.
- Anubis was an Egyptian god that watched over the mummy making process.
- The *Beautiful House* was the place where mummies were made.
- Barges carried mummies across the desert.

TEACHER'S COPY – Explorers (Literal)
LESSON 6: *Mummies & Pyramids, Ch. 3-5, pgs. 41-71*

3. **Explorer's Findings** - List the key events here – Who + What Happened. (15 min.)

EF1: Ancient Egyptians worshipped many gods and goddesses.
EF2: Ancient Egyptians believed people were made up of three parts: the body, the ka, and the ba.
EF3: After death, Egyptians believed people went to the "next life."
EF4: Mummies were dried out with salt and then wrapped in resin.
EF5: Good luck charms called amulets were wrapped in the mummy's linen to ensure a good next life.
EF6: Funeral processions carried the dead to the tomb.
EF7: People brought things to the funeral procession they thought the person would use in the next life.
EF8: "The Opening of the Mouth" ceremony made it possible for the dead person to eat, drink and speak in the Next Life.

4. **Important Questions** (15 min.)
If students do not know an answer encourage them to look back in the text or reread.

1. Who cared for the statues of the gods and goddesses? p. 42

A. pharaohs

B. servants

C. priests

D. ordinary people

(C)

2. What did ordinary people leave at the temples when they visited the temples? p. 43

(gifts)

3. The part of a person that includes their life force or what made the person alive is called the ___________ . p. 43 (ka)

TEACHER'S COPY – Explorers (Literal)

LESSON 6: *Mummies & Pyramids, Ch. 3-5, pgs. 41-71*

4. To ancient Egyptians, what did the ba look like? (p. 44)

A. a bird with a human head

B. a human with a falcon head

C. a human with the ears and tail of a lion

D. a woman with a cat's head

(A)

5. A mummy is a dead body protected from ______________. p. 55 (decay)

6. The Egyptian god _______________ watched over the mummy making process. p. 56 (Anubis)

7. What would the priests remove from the body? p. 57

(all the organs.)

8. What would the weight of a person's heart tell the priest? p. 57

(whether or not the person led a good life)

9. The Egyptians used natron to p. 58

A. wrap the mummy's body.

B. cover the linen strips around the body.

C. seal the mummy's sarcophagus.

D. help dry the body out quicker.

(D)

TEACHER'S COPY – Explorers (Literal)
LESSON 6: *Mummies & Pyramids, Ch. 3-5, pgs. 41-71*

10. A mask was placed over the mummy's face so that ____________ could recognize the person underneath. p. 59

(ba and ka)

11. Many amulets were in the shape of a beetle called a ________________. p. 62

(scarab)

12. What would the *Eye of Horus* amulet do for the mummies buried within? p. 63

(let them see outside the coffin)

13. The ________________________ was sort of like a parade. p. 65

(parade)

14. The funeral procession went first to the _____________________ . p. 67

A. tomb

B. burial chamber

C. house of the dead person

D. Beautiful House

(D)

15. To help them make the journey to the Next Life safely, mummies were buried with prayers, magic spells, and maps of the underworld. These prayers and spells and maps were called _______________________________________.

(The Book of the Dead)

Appendix C

Sample Fidelity Log for Inference Intervention Study

Inferential Condition: Reading Detectives Daily Log

Teacher___________________________________ Group ________________________________

<table>
<tr><th>Lesson</th><th>Date</th><th>Start Time</th><th>End Time</th><th>Students Absent</th><th>Notes</th></tr>
<tr><td>Introductory Lesson 1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Intervention Components (check all that apply):

o Followed script to introduce strategies.
o Students prompted to clarify text.
o Students prompted to look for clues.
o Students underlined clues in notebooks as they read text.

Overall, implementation of today’s lesson was (circle one):

4 – High 2 – Mid-low
3 – Mid-high 1 – Low or required section not included

Additional Notes:</td></tr>
<tr><th>Lesson</th><th>Date</th><th>Start Time</th><th>End Time</th><th>Students Absent</th><th>Notes</th></tr>
<tr><td>Introductory Lesson 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Intervention Components (check all that apply):

o Followed script to introduce strategies.
o Students prompted to clarify text.
o Students prompted to look for clues.
o Students underlined clues in notebooks as they read text.

Overall, implementation of today’s lesson was (circle one):

4 – High 2 – Mid-low
3 – Mid-high 1 – Low or required section not included</td></tr>
</table>

Additional Notes:

Lesson	Date	Start Time	End Time	Students Absent	Notes
Lesson 3: M&P Ch 1-2					

Intervention Components *(check all that apply)*:

- Completed warm-up activity for the day and discussed strategies.
- Read list of vocabulary words as students followed along in folders.
- Read text aloud to students as they followed along on pages.
- Prompted students to clarify.
- Prompted students to look for clues.
- Prompted students to make connections (text or outside).
- Prompted students to provide evidence.
- Praised and encouraged students for using strategies without prompting.
- Followed script for question types.
- Students answered questions and circled question type.
- Teacher discussed answers to questions if students completed independently.

Overall, implementation of today's lesson was *(circle one)*:

4 – High 2 – Mid-low

3 – Mid-high 1 – Low or required section not included

Additional Notes:

Lesson	Date	Start Time	End Time	Students Absent	Notes
Lesson 4: M&P Ch 3-5					

Intervention Components *(check all that apply)*:

- Completed warm-up activity for the day and discussed strategies.
- Read list of vocabulary words as students followed along in folders.
- Read text aloud to students as they followed along on pages.
- Prompted students to clarify.
- Prompted students to look for clues.
- Prompted students to make connections (text or outside).
- Prompted students to provide evidence.
- Praised and encouraged students for using strategies without prompting.
- Followed script for question types.
- Students answered questions and circled question type.
- Teacher discussed answers to questions if students completed independently.

Overall, implementation of today's lesson was *(circle one)*:

Appendix D

Egyptian Content Knowledge Assessment

NAME: ______________________________

Egyptian Knowledge Assessment

Directions: Please write your name at the top of this sheet. Listen while your teacher reads the following questions. If you don't know an answer, just give it your best guess. If you don't know how to spell an answer, just give it your best try. If your teacher doesn't know what you mean, they will ask you later. Don't tell any answers out loud. Use a piece of paper to cover your answers. Any questions?

1. A sarcophagus is a ______________________.
   a. a coffin
   b. an Egyptian funeral
   c. a mummy
   d. pyramid burial chamber

2. An Egyptian funeral procession took place when ______________________ died.
   a. any Egyptian person
   b. a priest
   c. an older person
   d. a royal person

3. Scepters are carried by ______________________ to represent that they have power.
   a. tomb robbers
   b. Egyptians
   c. Kings and Queens
   d. mummies

4. What are hieroglyphics used for?

____

5. Why was The Book of the Dead important to Egyptians?

____

6. Why did the Egyptians make mummies?

____

7. What were false passages used for in pyramids? P. 50
   a. tricking tomb robbers
   b. hiding treasures
   c. storing boats
   d. housing guards

8. What did it mean when a pharaoh wore a red and white crown?
   a. The pharaoh has Egyptian treasures.
   b. The pharaoh likes red and white.
   c. The pharaoh rules over both parts of Egypt.
   d. The pharaoh has two pyramids.

9. What does an Egyptologist do?

____

10. Amulet and Shawabti are examples of

Egyptian______________________________________.

11. Egyptians prayed for ________________________ when the Nile overflowed its banks each year.
    a. Spring
    b. Inundation
    c. The Book
    d. Kings and Queens

12. What does a sphinx look like?

____

13. What is meant when someone is called a "minion of Seth"?
    a. A little person from the the town of Seth
    b. A follower of the evil god Seth
    c. A magician from Seth
    d. A trouble maker

14. Why was the Nile important for Ancient Egyptians?

____

15. In Egypt, the Beautiful House was the place where the

________________________________were made.

16. Where were Pharaohs and wealthy Egyptians buried?

____

17. What famous Egyptian boy king died at the age of eighteen?

____

18. Egyptians believed if a dead person followed all the rules of the Book of the Dead then they would live happily forever in the next ______________________________.

19. Why did the pharaohs stop building pyramids?
   a. it cost too much
   b. it took too much time
   c. there weren't enough people to build them
   d. to hide their burial chambers from tomb robbers

20. ____________________ could be a pharaoh.

   a. a young boy
   b. a woman
   c. a man
   d. all of the above

Appendix E

Egyptian Comprehension Assessment Sample Passage and Questions

Name: ______________________________

The Cat – Not Just a Pet

Wild cats were first **domesticated** in Egypt thousands of years ago. Wild cats became domesticated after they became used to people and people started keeping them as pets. Both tamed and wild cats became **sacred** animals in ancient Egypt. They were worshiped and treated very specially. Cats were thought to come from the goddess Bastet, daughter of the sun god Re. Bronze statues of cats were found in an old temple near Zagazig, Egypt. Cats were often mummified and buried in special cat cemeteries. Sometimes the cats were buried with milk and mummified mice. Hundreds of thousands of cats were recently found in a cemetery in Thebes. Today, cats are not worshiped in Egypt. Some people in Egypt still have cats for pets. But other cats are not cared for by people. Wild swamp cats can often be found slinking around the Delta.

Adapted from *Enchantment of the World* (Heinrichs, 1997)

1. What does the word **domesticated** mean in this paragraph?

   ____

2. What does the word **sacred** mean in this paragraph?

   ____

3. Why did ancient Egyptians bury cats in cemeteries?

   ____

4. Zagazig was a ______________ in ancient Egypt. (Circle the best answer)
   a. Temple
   b. Place
   c. Statue
   d. Name of a special cat

5. Why did people mummify their cats and bury them with milk?

____

6. How do people feel about cats in Egypt today?

____

7. Where can wild cats be found in Egypt today?
   a. Zagazig
   b. Bastet
   c. Delta
   d. Thebes

8. Where were wild cats first domesticated?
   a. Egypt
   b. Bastet
   c. Delta
   d. Thebes

9. How many years ago did the first wild cats become pets?
   a. Hundreds
   b. Thousands
   c. One hundred
   d. Millions

10. Who was Bastet's father? ______________________

King Tut's Treasure

In 1922, a British archeologist named Howard Carter found the famous tomb of King Tut, or Tutankahamen. The boy-king was buried in the Valley of the Kings. He ruled Egypt from age 9 until he died at age 18. King Tut is not famous for what he did when he was alive. He is well known today, because his tomb is one of the most **intact** tombs ever discovered. Unlike other tombs that had been robbed and destroyed, most of the objects were intact. They had not been moved or broken like pieces of treasure found in other discovered tombs. The items were found just as they had been left 3,000 years ago. Archeologists believe that tomb robbers tried to take some items on two occasions but couldn't get all the way into the tomb. So, only a few items were out of place or broken. More than 5,000 objects were found in King Tut's tomb including furniture, walking canes, games, weapons and a golden chariot. Among the clothes found were 28 pairs of gloves, 25 head dressings, and 145 loincloths.

1. Why were there so many objects in King Tut's tomb compared to other tombs that had been discovered?
   a. King Tut had more treasure than other pharaohs
   b. The curse had kept robbers away from the treasure
   c. King Tut was more famous than the other pharaohs
   d. Tomb robbers did not get all the way into his tomb

2. What does the word **intact** mean?

   ____

3. Why did they find so many clothing items in the tomb?

   ____

4. How many times had robbers gotten into the tomb?
   a. 0
   b. 1
   c. 2
   d. 3

5. Where was King Tut buried?
   a. In a pyramid
   b. Cairo, Egypt
   c. The Valley of Kings
   d. Thebes

6. Why is King Tut called the boy-king?
   a. He died when he was a young boy
   b. He started ruling when he was a young boy
   c. All pharaohs were called boy-kings
   d. All of the above

7. Why is King Tut famous?
   a. He was a rich pharaoh
   b. He was a good ruler and his people loved him
   c. His tomb was not destroyed by robbers
   d. He had more treasures than any other pharaoh

8. How many years ago did King Tut die?
   a. 1,000
   b. 5,000
   c. 1922
   d. 3,000

9. When was King Tut's tomb discovered?
   a. 1922
   b. 1900
   c. 3000 B.C.
   d. the story doesn't say

10. Name two of the objects that were found in King Tut's tomb.

CHAPTER III
STUDY TWO

Introduction

Best practices for early reading instruction have been established (Adams, 1994; National Reading Panel, 2000); however, the challenge of supporting readers at the middle and high school level remains, as evident by national and international data on reading comprehension proficiency. For example, the 2017 National Assessment of Educational Progress (NAEP; National Center for Education Statistics, 2017) found only 35% of eighth-grade students were able to comprehend grade-level text. Explanations for this vary, but students' lack of background knowledge and the resulting effect on comprehension has been a recurring theme in the literature (Cromley & Azevedo, 2007; Kintsch & Rawson, 2005; Oakhill, 1984; van den Broek, 2010). Theories of reading comprehension emphasize the importance of background knowledge and inference to build a full representation of the text. Kintsch (1998) defines comprehension as a process of integrating a literal representation, comprised of relationships among words, sentences, and larger portions of the text, with background knowledge to generate the inferences that produce deeper meaning. Cromley and Azevedo (2007) build upon this model, adding that background knowledge is an important predictor of reading comprehension, as it precipitates the use of reading strategies, which in turn contribute to inferential processes. In both theories, background knowledge plays a central role in making meaning of a text.

One solution that addresses ways to build background knowledge and improve reading comprehension is the use of integrated instruction (Dennis, Parker, Kiefer, & Ellerbrock, 2011; Vacca, 2002). Integrated instruction, broadly defined, is the process of two disciplines functioning as one—in true models of integration, it would be impossible to tell when instruction in one subject ends and another begins (Stoddart, Pinal, Latzke, & Canaday, 2002). Ideally, integrating literacy with other content provides opportunities to build background knowledge and improve comprehension simultaneously, connecting learning by capitalizing on the shared processes of both disciplines.

Integrating Literacy and Science

The document-based nature of social studies makes it a logical setting for the integration of literacy. However, research is also emerging on less-expected disciplinary pairings as definitions of literacy evolve beyond basic word reading and comprehension skills. One such domain is that of science, in which content experts advocate the inclusion of literacy to support learning in the discipline. The NRC includes in the Framework for K-12 Science Education (2012) the practice of "obtaining, evaluating, and communicating information." Literacy is an inherent part of scientists' work, facilitating both the construction and communication of knowledge (Hsu, Yen, Chang, Wang, & Chen, 2016; Norris & Phillips, 2003; Osborne, 2002).

Research has established a strong correlation between reading and science achievement (Cromley, 2009), suggesting certain practices in reading, such as asking questions and drawing inferences, are associated with students' science achievement (Chin & Osborne, 2008). Both science learning and reading comprehension rely heavily upon individual and contextual factors, making their relationship complex, but necessary, to study (Cano, Garcia, Berben, & Justicia, 2014). The RAND Reading Study Group (Snow, 2002) described comprehension as the interaction of three variables—the text itself, the reader, and the context in which reading occurs. The interplay of these variables exists as the reader constructs a mental representation of the text (Kintsch, 1998). Similarly, science inquiry is considered a process of creating meaning and making sense of concepts relative to personal knowledge and interactions with others (Lara-Alecio et al., 2012). With shared processes at its core—for example, questioning, making inferences, and summarization (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012), the practice of science and reading integration has been considered effective for improving student learning in science at both the elementary and secondary levels (Cheung, Slavin, Kim, & Lake, 2017).

Expository text has an important role in building knowledge (Cervetti, Jaynes, & Hiebert, 2009; Marzano, 2004), but less clear are the practices that can be used effectively across the curriculum, and with what populations of learners, to improve comprehension of such text and build knowledge simultaneously. Background knowledge is of critical importance for content retention (Norris & Phillips, 2003). Experts in a content area organize new learning around important concepts; therefore, a broad knowledge base contributes to deeper understanding of new content and its transfer to other contexts (Bransford, Brown, & Cocking, 2000). Even with a growing body of empirical research to support the integration of literacy and science to build knowledge, the most effective role of text in science instruction—using text to teach generalizable comprehension strategies, situating it in a disciplinary approach, or some combination of both—has not been clearly defined.

Science Text Used in a Disciplinary-Based Approach

Under this approach, authentic science text is used to build conceptual knowledge and to teach strategies based upon the shared inquiry processes of literacy and science or the specialized language of science (Greenleaf et al., 2011; Guthrie & Alao, 1997). Strategies specific to reading science text are learned and applied flexibly with teacher scaffolding to help students construct meaning (Holliday, Yore, & Alvermann, 1994). Studies with disciplinary-based approaches used text in the following ways.

Text to Investigate. Text is interspersed with hands-on science instruction and the investigations essential to "doing" science, as well as to generate ideas and more deeply process learning (Barber, Catz, & Arya, 2006). For example, in a study by Chen, Chen, and Ma (2014), first-grade students observed insects, generated questions, then selected related text and reviewed reading comprehension strategies relevant to the science text they read. The experimental group performed statistically significantly better on measures of memory and comprehension; the authors conclude the intervention was effective in learning of both factual and conceptual knowledge.

Text to Communicate as a Scientist. Text used in a disciplinary model also provides the practice necessary to become an informed consumer of scientific information, often referred to as being "scientifically literate" (Krajcik & Sutherland, 2010). In a study by Chen (2011), seventh-grade students were taught strategies to evaluate text sources and synthesize information into a written report. Intervention students outperformed control students on measures of problem solving and comprehension, but not on factual recall. The authors conclude this may be because the inquiry-based science curriculum did not emphasize factual content, corroborating studies that show inquiry-based instruction to be less effective for rote memorization (Chang & Mao, 1998; Hung, Jonassen, & Liu, 2008). Disciplinary literacy teaches the metacognitive awareness necessary for comprehending all types of science writing (Yore, Bisanz, & Hand, 2003). Similar to the active process of inquiry used in science, students learn to interact with the text and investigate its meaning (Dickinson & Young, 1998) in the way an expert scientist would. For example, a study by Guzzetti and Bang (2010) used text to teach the analysis, inference, and reasoning processes typically used by scientists as students communicated their learning. In the intervention, students read and analyzed forensic stories and made inferences from written excerpts of crime scenes to learn the processes scientists use to investigate crime. Students in the intervention group made statistically significant gains on measures of science achievement as compared to a control group. In a similar study, Spektor-Levy, Eylon, and Scherz (2009) implemented a "scientific communication" curriculum in which students focused on finding, organizing and presenting information through scientific reading and writing. Students receiving the instruction performed better than comparison students on measures of science content knowledge and scientific communication skills. Studies by Tsai, Chen, Chang and Chang (2013), Michalsky, Mevarech, and Heibi (2009), and Osman and Hannafin (1994) all incorporated metacognitive strategies to connect prior science knowledge to current science learning through text; students using these strategies outperformed students in the control group.

Text to Learn the Language of Science. Related to communicating in science, several studies focused on the specialized language processes of the discipline. August, Branum-Martin, Cardenas-Hagan, and Francis (2009) used a vocabulary intervention called Quality Science and English Teaching (QuEST) that also paired direct instruction of science vocabulary with reading, writing, and visual support. In comparison to students receiving traditional instruction, students in the QuEST program scored higher on measures of science knowledge and vocabulary. An intervention by Larson (2014) designed to unlock the code of science language used a conceptual, generative vocabulary matrix to assist students in making the domain-level connections among academic and technical words as they generated ideas through discussion and ongoing feedback. Intervention students demonstrated higher levels of conceptual science knowledge than students who did not receive the instruction. Overall, using text to support the specific academic language of science has been effective in improving vocabulary and science content knowledge for different types of learners.

Text to Connect Core Processes of Disciplines. Other integrated curricula using text in ways characteristic of disciplinary literacy were developed on the premise that science and literacy share “synergistic” processes such as prediction, inference, questioning, and summarization. Capitalizing on these shared processes potentially enhances both reading and science learning, as the specialized skills of being a scientist are similar to those employed by skilled readers (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012; Girod & Twyman, 2009). One large-scale integrated science and literacy curriculum, *Seeds of Science/Roots of Reading* (SEEDS; Girod & Twyman, 2009) makes these shared processes transparent to students. For example, students are taught prediction in the context of hands-on science activities and also during reading of science text. The similarities of making predictions in both disciplines are explicitly stated and discussed with students. The SEEDS curriculum has been studied at different grade levels (ranging from Kindergarten to grade 8) within varied strands of science (earth, space, and life science), and overall, has been effective in improving science content learning and science vocabulary knowledge (Pearson, Knight, Cannady, Henderson, & McNeill, 2015).

It is important to consider that studies using text in this way are either researcher-delivered interventions, or, if teacher-delivered, a significant amount of guidance has been provided. For example, the work of Greenleaf et al. (2011) used a ten-day professional development model to prepare teachers to teach the practices central to science reading as part of the Reading Apprenticeship intervention. The study measured outcomes for teachers and students as compared to control classrooms, and found that the intervention increased teachers' ability to integrate literacy with science as measured by their knowledge of the role reading plays and their facility with instructional practices. Students in the intervention performed better on state standardized assessments of reading comprehension and biology.

It is also important to note that not all studies using a disciplinary literacy approach measured effects on reading comprehension. Though initial research suggests integration in this manner is effective for improving science content knowledge, limited conclusions can be drawn about its benefit to reading comprehension.

Science Text Used in a Content-Area Reading Approach

Another perspective is that the purpose of science text is to deliver content, and reading comprehension strategy instruction in the science setting improves access to this content. Instruction and practice with reading comprehension strategies is particularly important for struggling readers, who are unlikely to apply them spontaneously as typical readers do (Torgesen, 1977). Without effective strategy use in reading science text, science learning may be adversely affected, particularly if text is the primary means of content delivery (Casteel & Isom, 1994; Faggella-Luby, Graner, Deshler, & Drew, 2012). Strategy instruction provides students with specific actions to take when making sense of text. Studies using this approach are consistent with the recommendation that direct and explicit strategy instruction is effective in improving comprehension (Duke & Pearson, 2008; McNamara & Kendeou, 2017; National Reading Panel, 2000; Oakhill & Patel, 1991; Swanson & Hoskyn, 2001). Additionally, this perspective suggests that while the shared processes of science and reading are mutually supportive, their methods are discipline-specific and should remain so (Dickinson & Young, 1998). Using text in a method consistent with content-area reading does not preclude hands-on or inquiry-based science practices in favor of reading strategy only. A disciplinary approach uses strategy instruction as well—the difference is the strategies provided in a content-area approach are generalizable reading comprehension strategies meant to improve access to expository text. For example, Fang and Wei (2010) base their work on the idea that students are unable to attain scientific knowledge without the ability to read, and students often do not have a firm grasp on the strategies necessary for comprehending expository text. The study used reading strategy lessons and a home science reading program for students to practice predicting, questioning, concept mapping, paraphrasing, and note taking. Students in the intervention group performed statistically significantly higher on the Gates subtests of reading comprehension and vocabulary, as well as on a researcher-created measure of science knowledge.

Several studies have analyzed expository science text and found it to be abstract and exceedingly difficult in its language and structure (Flesch, 1948; Halliday, 1993; Lemke, 1990). Beyond that, science text presents the unique challenge of synthesizing information across multiple modes of representation (i.e., text, diagrams, graphs, and tables; Hsu, Yen, Chang, Wang, & Chen, 2016). To learn content from text, a competent science reader must navigate demands on working memory, apply strategies as needed to monitor and repair comprehension, and integrate new and existing knowledge (van den Broek, 2010; Yore, 2000). Several studies have implemented strategies to improve comprehension of science text via direct instruction in science vocabulary, the use of graphic organizers, concept mapping, and mnemonic strategies (Guastello, Beasley, & Sinatra, 2000; Kaldenberg, Watt, & Therrien, 2015; Radcliffe, Caverly, Hand, & Franke, 2008).

Lara-Alecio et al. (2012) incorporated direct instruction of vocabulary in a scripted intervention using science expository text. The intervention program, Content Area Reading in Science for English Literacy and Language Acquisition (CRISELLA), also included student-friendly definitions of vocabulary, visual scaffolding, and opportunities for students to use the words in discussion and writing. Students in the intervention made statistically significant gains on near and far-transfer measures of reading achievement, and also in reading fluency on the DIBELS Oral Reading Fluency measure. However, though students in the treatment group improved science achievement on district-level benchmark assessments, they did not statistically significantly differ from students in the control group on state assessments of science achievement. The authors suggest this may be due to proximity of the assessment.

Tong, Lara-Alecio, Irby, and Koch (2014) explored the differences in how science and literacy might best be integrated for elementary students who were still learning basic reading skills and later, middle school students who were transitioning to text-based learning. Using an interdisciplinary approach, the longitudinal study shifted the primary focus from English-based in the elementary years to science-based in the middle school setting. Results showed that elementary students in the intervention improved in reading fluency and comprehension relative to a control group; middle school intervention students outperformed students receiving traditional instruction on measures of fluency, vocabulary, and science and reading achievement. The intervention was more effective when students participated in the intervention at both the elementary and middle stages rather than only one time period. The authors concluded that integrating literacy in the content areas must be an ongoing practice if students are to master science content knowledge.

Another integrated curriculum, *IDEAS*, has been studied for more than 20 years in elementary school settings (Vitale & Romance, 2010). Developed to address the lack of instructional time for science, the program replaces traditional reading programs with one of science reading. In two-hour blocks, students learned science using a knowledge-based approach with applied reading activities after hands-on investigations. In a 1992 study, fourth-grade students learned content reading strategies such as identifying main idea or cause and effect; they also worked with visual representations of text by concept mapping and learning how to interpret graphics such as tables or charts. When compared to a control group, students participating in IDEAS instruction performed better on measures of science and reading achievement.

Bravo and Cervetti (2014) added a component of explicit reading comprehension strategy to their intervention, and found that students in treatment groups were superior to the control group on measures of vocabulary and science achievement, but not on measures of reading comprehension. The authors suggest time may have been a factor, with an eight-week intervention not enough to show a difference in reading comprehension on a far-transfer measure.

Descriptive analysis of the research reviewed here has been compiled (Bradbury, 2014), however, no quantitative summary exists. Therefore, a meta-analysis will be conducted for studies that integrated literacy with science instruction to answer the following questions: 1) for both literacy and science outcomes, what is the weighted mean effect size of studies that integrate literacy and science instruction, 2) what participant variables may be associated with effect size, 3) within an integrated science and literacy curriculum, what intervention characteristics are associated with effect size?

Method

A comprehensive search of the literature was conducted to identify all existing studies of integrated science and literacy instruction from 1950 to present. An electronic search using the ERIC and PsychInfo databases yielded 3,072 citations for consideration, based upon the terms *integrated science* AND *literacy; disciplinary literacy* AND *science*; *content literacy* AND science; *science* AND *reading comprehension*; *content area reading* AND *science*. Additionally, we reviewed the reference lists of previous research syntheses (Bradbury, 2014; Kaldenberg, Watt, & Therrien, 2015; Swanson, 1999) and hand-searched the following journals: *International Journal of Science Education*, *Journal of Elementary Science Education*, and *Journal of Research in Science Teaching*. In total, 105 articles were read and considered for inclusion.

Inclusion Criteria

The studies were then evaluated based upon the following inclusion criteria: a) participants were of school age (grades K-12), b) the study used an experimental or quasi-experimental design and reported enough information to calculate an effect size, and c) the intervention consisted of *intentional* science and literacy instruction.

Because our definition of integration was based in equal (or near-equal) attention to both disciplines, we developed criteria for the type of instructional practices characteristic of intentional integrated science and literacy instruction. Our criteria are based in our review of science and literacy integration research.

Intentional science instruction was defined by attention to science content as evidenced by meeting *both* of the following criteria: 1) the topic of the science instruction was based on an identifiable NGSS science and engineering practice or core idea, and 2) the study included a dependent variable that measured the science content knowledge presented in the intervention. Using the NGSS science and engineering practices and core ideas helped further develop the criteria that the intention of instruction was science learning, rather than literacy instruction that simply used science text with no significant attention to the science content.

In order to answer our research question on the effect of integrated instruction on literacy achievement, we chose studies that focused on the construct of reading comprehension, specifically comprehension of science texts. Therefore, though within the broader scope of literacy and science integration, studies that only addressed writing in science were excluded. To be considered for inclusion, the study must have used science text in one or more of the following ways: 1) to teach content-area reading strategies (i.e., SQ3R or other textbook-reading strategies, use of graphic organizers, identification of text structure, and semantic or concept mapping), 2) to teach information literacy strategies, including the use of read-alouds or trade books for students to develop and/or research questions *or* to teach disciplinary literacy strategies aligned with scientific literacy practices that encouraged students to use text authentically as a scientist would, and 3) for direct and/or strategy-based vocabulary instruction in the context of science reading. The majority of the 105 studies reviewed were excluded on the basis of methodological criteria because they did not use an experimental or quasi-experimental design (Colwell, Hunt-Barron, & Reinking, 2013; Kinniburg & Baxter, 2012; Lee, Deaktor, Hart, Cuevas & Enders, 2005; Spence, Yore, & Williams, 1999; Webb & Rule, 2012). Other examples of studies excluded include those that did not include a science outcome (Cohen & Johnson, 2012; Rogevich & Perin, 2008), studies that did not report enough information to calculate an effect size or report results at the individual level of analysis (Cervetti, Barber, Dorph, Pearson, & Goldshmidt, 2012; Morrow, Pressley, Smith, & Smith, 1997), studies not conducted in a K-12 setting (Baker and Pilburn, 1990; French, 2004), or studies addressing only writing in science (Honig, 2010; Rivard & Straw, 2000). A total of 32 studies met inclusion criteria. From those studies, 14 reading comprehension outcome effect sizes and 36 science outcome effect sizes were able to be calculated and were considered in the final analysis (see Table 5).

Table 5
Studies Selected for Inclusion with Moderator Analysis Variables

	Science Effect Size	Literacy Effect Size	Standardized Measure	Treatment *N*	Control *N*	Ongoing PD	Concept Mapping	Hands-On Activities	Content Area Approach
Anderson (2005)	1.38			42	44			x	
August, Branum-Martin, Cardenas-Hagan & Francis (2009)	0.03			158	170	x	x	x	
Barber, Catz, & Arya (2006a)	1.06			304	170			x	
Barber, Catz, & Arya (2006b)	0.37			314	112			x	
Bravo & Cervetti (2014)	0.36	-0.33		77	95		x	x	x
Chen (2011)	2.10			32	32			x	
Chen, Chen, & Ma (2014)	0.03			30	30		x		
Duesbery, Werblow, & Twyman (2011)	0.17	0.06		314	112			x	
Fang & Wei (2010)	0.48	0.50	x	140	93	x	x	x	x
Girod & Twyman (2009)	1.40			26	26			x	
Greenleaf et al. (2011)	0.17	0.24	x	618	618	x			
Guastello, Beasley, & Sinatra (2000)	5.96			62	62		x		x
Guthrie et al. (1998) – Grade 3	0.59	0.23		48	42	x		x	x
Guthrie et al. (1998) – Grade 5	1.17	0.04		40	42	x		x	x
Guzzeti & Bang (2011)	1.16			99	97		x	x	
Lara-Alecio et al. (2011)	-0.18	0.19	x	166	80	x		x	
Larson (2014)	1.43			144	78	x	x	x	x
Michalsky (2013)	1.42			49	46	x			
Michalsky et al. (2009)	0.46			27	27	x			
Nelson, Watson, Ching, & Barrow (1996)	2.08			15	15				x
Ortlieb & Norris (2012)	0.40			17	19			x	
Osman & Hannafin (2001)	1.34			38	35				
Radcliffe, Caverly, Hand, & Frank (2008)	1.28			23	27	x	x		x
Ritchey et al. (2012)	0.64			56	66				x
Romance & Vitale (1992)	1.54	0.51	x	51	77	x		x	x
Romance & Vitale (2010)	0.67	0.37	x	261	183	x	x	x	
Romance & Vitale (2011a) – Grade 1	1.13	0.43	x	43	50	x	x	x	
Romance & Vitale (2011a) – Grade 2	0.80	1.22	x	49	54	x	x	x	
Romance & Vitale (2011b) – Grade 1	0.35	0.25	x	54	99	x		x	
Romance & Vitale (2011b) – Grade 2	0.25	0.39	x	43	67	x		x	
Rule & Webb (2015)	2.60			23	23			x	
Simmons, Griffin, & Kameenui (1988)	0.22			14	15		x		
Spektor-Levy, Eylon, & Scherz (2009)	0.93			57	42	x			
Stephens (2007)	0.08		x	40	16	x			x
Tong et al. (2014)	0.15	0.68	x	94	194	x		x	
Tsai, Chen, Chang, & Chang (2013)	4.04			56	62				

Coding

After identifying studies for inclusion, each eligible study was coded by two trained doctoral students. Interrater agreement, calculated as a percentage of agreement for each category coded, ranged from 78% to 100%. Any discrepancies were able to be resolved after rereading the article and discussing coding decisions until 100% agreement was reached for each category. The variables that follow were coded as moderators, based on an initial review of the literature that determined which could potentially explain any observed heterogeneity of effects.

Participant Variables

Socioeconomic Status and Academic Achievement. Studies were coded to examine any participant variables that may confound results, such as socio-economic status (coded as low if more than half the sample was classified as having free and reduced lunch, or if otherwise stated) and academic achievement (coded as low if stated by the author, or if not stated, assumed to be average).

Grade Level. To consider the effect of integrating science and literacy at different grade levels, studies were classified as early elementary (K-2), upper elementary and middle school (3-8), and secondary (9-12). Given the developmental trajectory of students at these different stages (as they transition from learning to read to reading to learn (Chall, 1983), the outcome of studies may be moderated by the age of the student. Divisions were determined based on Shanahan and Shanahan's (2008) classification that outlines a progression from basic literacy (word reading and fluency in the early elementary years) to intermediate literacy (use of generic comprehension strategies in the upper elementary to middle school years), to disciplinary literacy (more specialized literacy practices that develop in the high school years).

Table 6
Participant Variables of Studies Included in Effect Size Analysis

	Science (*k* = 36)		**Literacy** (*k* = 14)	
	N	%	*N*	%
Socioeconomic Status: Low	11	31	7	50
Reading Ability: Low	9	25	5	36
Grade Level				
K-2	11	31	4	29
3-5	12	33	8	57
6-8	8	22	1	<1
9-12	5	14	1	<1

Outcome Variables

Measures were coded as standardized or researcher-created, so that the relationship between each and effect sizes could be examined, as standardized measures typically result in lower effect sizes (Scammacca et al., 2007). Some researcher-created measures aligned closely to the intervention content, so differences in effect sizes may be a result of the content of the outcome and students' ability to transfer learning to novel tasks.

Intervention Variables

Duration. The length needed to achieve positive effects in an intervention is a variable of interest in reading comprehension research. For example, in a meta-analysis of inference interventions, Elleman (2017) found positive effects for students in treatment groups with 10 hours or less of instruction. Similarly, the length of an integrated literacy intervention may contribute to the outcome and is a question of practicality, given the rigidity of daily schedules in middle and secondary grades. Because studies did not consistently provide exact times, duration was coded as a) short-term (for example, one unit of instruction, or a 3-month intervention), or b) long-term (a year-long intervention).

Ongoing Professional Development. As stated previously, one explanation for limited literacy instruction in the content areas is that teachers are unsure of the best way to address students' challenges with comprehension of science texts (Greenleaf et al., 2011). Studies were coded based on the level of support teachers received in implementing the intervention—if teachers received ongoing support and professional development throughout the intervention or an introduction to the intervention with no further support. Some studies, for example, included a one-time session to introduce the intervention materials, or provided self-guided teacher directions for the intervention; studies coded as having ongoing professional development offered regular collaboration among researchers and teachers to support instruction.

Metacognition. Science text, in particular, requires a set of processes that allow for constant reconciliation of prior and new knowledge. Some research suggests that direct instruction in metacognitive practices for reading of science text improves content knowledge in science (Quinn & Wilson, 1997). Studies were coded as having a metacognitive element if participants were provided with direct and explicit instruction in the practice and were encouraged to use metacognitive prompts while reading.

Hands-On. In reviewing studies for inclusion, some variability existed in the approach toward hands-on instruction. For example, some studies used text to supplement hands-on instruction, and students explored text for second-hand evidence after completing investigations (Bravo & Cervetti, 2014). Other studies highlight the necessity of science instruction that does not rely on hands-on activity for the sake of an activity, but rather develops an in-depth understanding of the processes and content of the science behind an experiment (Greenleaf, 2011). The inclusion of hands-on instruction could certainly play a role in varying levels of engagement or in establishing real-world connections that benefit learning (Guthrie & Alao, 1997), and so was included as a moderator variable.

Discussion. In the IES Practice Guide for Improving Adolescent Literacy, Kamil et al. (2008) recommend opportunities for extended discussion of text meaning and interpretation. The authors further define this as sustained, in-depth interaction rather than a teacher to student question and answer exchange. The guide cites evidence for higher literacy outcomes in classrooms that implemented student discussion in this manner; therefore, it was coded as a moderator variable because interventions that include this may produce varied results.

Concept Mapping. One challenge in reading science text is navigating complex expository structures (Cook & Mayer, 1988); therefore, representations that reduce content to only the most important concepts can be beneficial (Carnine, 2004), particularly when using non-cohesive text such as that found in many science textbooks (Chambliss & Calfee, 1989). Based on this research, it was hypothesized that use of these elements in with content-area text could produce different outcomes.

Vocabulary. The academic language of content areas is particularly complex and may impede comprehension of scientific texts (Boyd, Sullivan, Popp, & Hughes, 2012; Chall, 1983; Gee, 2001). It could be reasonably expected that attention to vocabulary within an integrated model may influence the learning and retention of content. Studies coded in this category provided vocabulary instruction (for example, direct explanations or as part of a concept map).

Content Area Reading or Disciplinary Literacy Approach. Studies did not directly state which approach of literacy integration was intended; however, characteristics of each were defined and coded as follows. To be coded as aligned with content-area reading approaches, the intervention: a) provided direct strategy instruction generalizable to any expository text, and b) was intended to improve comprehension of expository text as a means for content learning. To be considered a disciplinary approach, the intervention: a) emphasized strategies that are unique to the way scientists read and interpret text, and b) was intended to improve scientific literacy and communication as a means for content learning. Though some studies may have elements of both content area and disciplinary literacy, the preceding criteria provided a reliable way to categorize the overall approach to strategy instruction in the intervention.

Table 7
Features of Studies used in Effect Size Analysis

	Science (*k* = 36)		**Literacy** (*k* = 14)	
	N	%	*N*	%
Duration: Year-Long	12	33	10	71
Professional Development	19	53	12	86
Metacognition	10	28	3	21
Hands-on Activities	23	64	13	93
Discussion of Text	25	69	12	86
Concept Mapping	12	33	5	36
Vocabulary Instruction	13	36	6	43
Content-Area Strategy Approach	11	31	4	29
Disciplinary Literacy Strategy Approach	25	69	10	71

Analysis

Effect sizes for each study were calculated using the Cohen's *d* statistic, representing the difference between the treatment and control group means, divided by the pooled standard deviation of each mean. The resulting value was then adjusted using the Hedge's *g* correction, which adjusts for the slight overestimation of effect size in studies with smaller samples (Hedges, 1981).

One outcome variable for science and one for literacy (when available) was selected to avoid dependency in effect sizes (Lipsey & Wilson, 2001). For science, the measure that best represented the content learned was chosen—for example, several science studies included an assessment of factual content and a far transfer measure of scientific literacy or inquiry practices. Because this analysis seeks to determine effectiveness of literacy on content learning, the measure of factual content was used. In literacy, measures of reading comprehension were used. Two unique data sets with science outcomes and literacy outcomes were created that contained, for each study, an effect size and its standard error and variance. Prior to analysis, each data set was evaluated for outliers by considering the distribution of effect sizes. Using Tukey's (1977) criteria, outliers were defined as any effect size falling 1.5 times outside the interquartile range, as calculated by determining the upper (75th percentile) and lower (25th percentile) values of the distribution. No effect sizes were outside the range of the upper or lower fence (-7.76 and 8.28 for science; -0.501 and 0.818 for literacy, respectively) and therefore none were removed from the final analysis. Sample size outliers were also calculated; however, none fell outside the range of acceptable values.

Both sets of data were then analyzed separately using Stata/IC 15.1 software to determine the weighted mean effect. Macros used in this analysis include metan (Bradburn, Deeks, & Altman, 1998) and metareg (Wilson, 1998). Because a great deal of variability between studies beyond standard error was anticipated due to participant variables or intervention characteristics, a random effects model was selected *a priori* as the appropriate method of analysis (Borenstein, Hedges, Higgins, & Rothstein, 2011). Random effects models assume the absence of one true effect size; rather, the true effect sizes of studies are normally distributed. A random effects model results in a weighted mean that takes into account both the within- and between-study variance.

In addition to determining a weighted mean effect, measures of variance were considered, including the Q statistic, which partitions within- and between-study error to determine if heterogeneity in effect sizes exists. Q is calculated as:

$$Q = \sum_{i=1}^{k} W_i \, (Y_i - M)^2 \qquad (1)$$

Beyond that, to estimate the proportion of variance that can be attributed to true differences in the effect sizes, rather than random error, the I^2 statistic will be evaluated. This value can be interpreted as a signal-to-noise ratio of between-study variance to total variance, and as such is not affected by the number of studies (Borenstein, Hedges, Higgins, & Rothstein, 2011). The formula for I^2 is:

$$I^2 = \left(\frac{Q - df}{Q}\right) \times \, 100\% \qquad (2)$$

Results

Descriptive Characteristics of Studies

Science Outcomes. The majority of studies included participants of average socio-economic status (69%), and average reading ability (75%). A total of 11 studies were conducted in elementary settings (K-5), with the remaining 25 studies in grades 6-12. Fewer than half of the studies were year-long in duration (33%). In 53% of the studies, teachers providing the intervention were offered ongoing professional development in the form of additional sessions to learn methods of teaching the intervention or collaborative planning meetings with researchers to clarify practice. Within the science analysis, 70% of the effect sizes were derived from a researcher-created measure to assess science content, with the remaining from a standardized measure. Of the instructional variables coded, the most frequently included in studies were hands-on science instruction (64%) and an emphasis on student discussion of the content (69%). Approximately half of the studies used the text as a follow-up to initial science instruction, while the other half implemented science instruction and use of text simultaneously. In terms of specific strategy use, 27% of studies provided instruction in metacognitive strategy, and 33% instructed students to use concept maps. Direct instruction of science vocabulary occurred in 36% of the studies. Only 27% of the studies were coded as providing strategy instruction consistent with a generalizable, content-area reading approach. The remaining studies emphasized strategies specific to science reading and the practice of scientists.

Literacy Outcomes. Of the students for studies included in the literacy analysis, approximately half were from a low socioeconomic setting, and 36% of studies were with students of low reading ability. The literacy effect sizes came from mainly grades 3-5 (57% of studies), and were year-long interventions (71% of studies). For literacy outcomes, 71% of the effect sizes were from standardized measures, and only 4 of the 14 from a researcher-created measure. Instructional strategies most used were use of hands-on activities in science (93% of studies), and discussion of the content or text (86% of studies. Across studies with a literacy outcome, 86% provided teachers with ongoing professional development. The majority of studies in the literacy analysis used a disciplinary literacy approach (71% of studies).

Overall Effect

Science Outcomes: Science Content Knowledge. Effect sizes for science outcomes (k = 36) ranged from -0.18 to 5.9. The overall weighted mean effect for measures of science content knowledge was 1.04 ($p < .01$), indicating that students learning within an integrated model of science and literacy instruction outperformed those who did not on measures of science content learning. The Q statistic was significant, Q_d (35) = 672.31, $p < .01$); therefore, effect sizes were heterogeneous. According to the I^2 value, 94.8% of the observed variance can be attributed to heterogeneity between studies. Guidelines from Higgins and Green (2011) suggest that an I^2 value in the range of 75-100% represents considerable heterogeneity. Tests of the null hypothesis (z = 8.45, $p < .01$) indicated the effect size was statistically significantly different than zero.

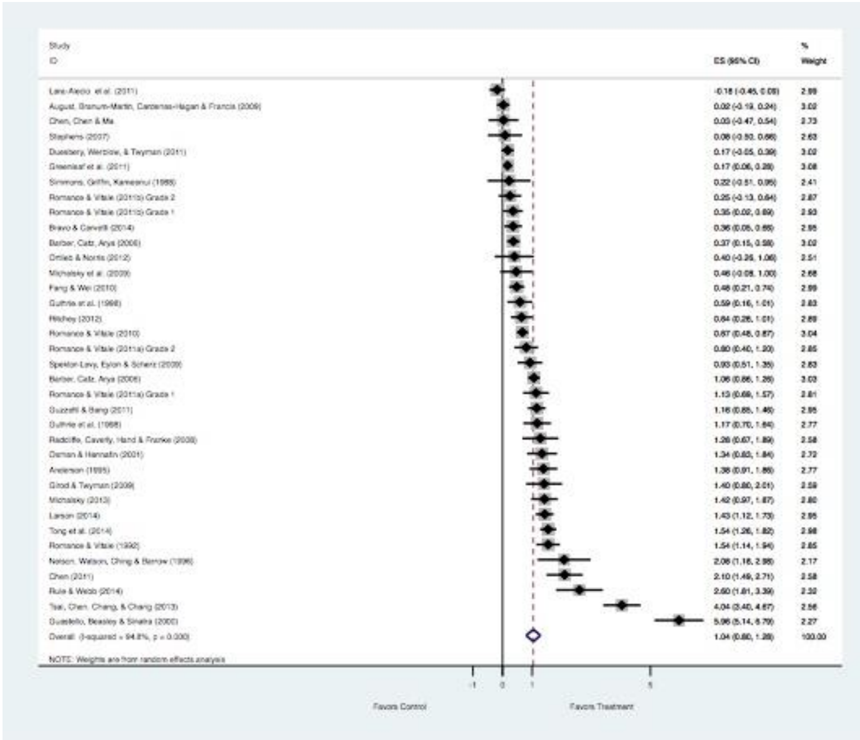


Figure 2. Forest Plot of Science Effect Sizes.

Literacy Outcomes: Reading Comprehension. Literacy outcome effect sizes (k = 14) fell in a range of -0.32 to 0.67. The overall weighted mean effect for measures of reading comprehension was 0.245 ($p < .01$). The Q statistic was significant, Q_d (13) = 48.22, $p < .01$), again indicating effect sizes were not homogenous, with an I^2 value showing 73% of the variance to be attributable to heterogeneity. According to the Higgins and Green (2011) guidelines, this value represents substantial heterogeneity. For literacy outcomes, tests of the null hypothesis (z = 3.86, $p < .01$) indicated the effect size was statistically significantly different than zero.

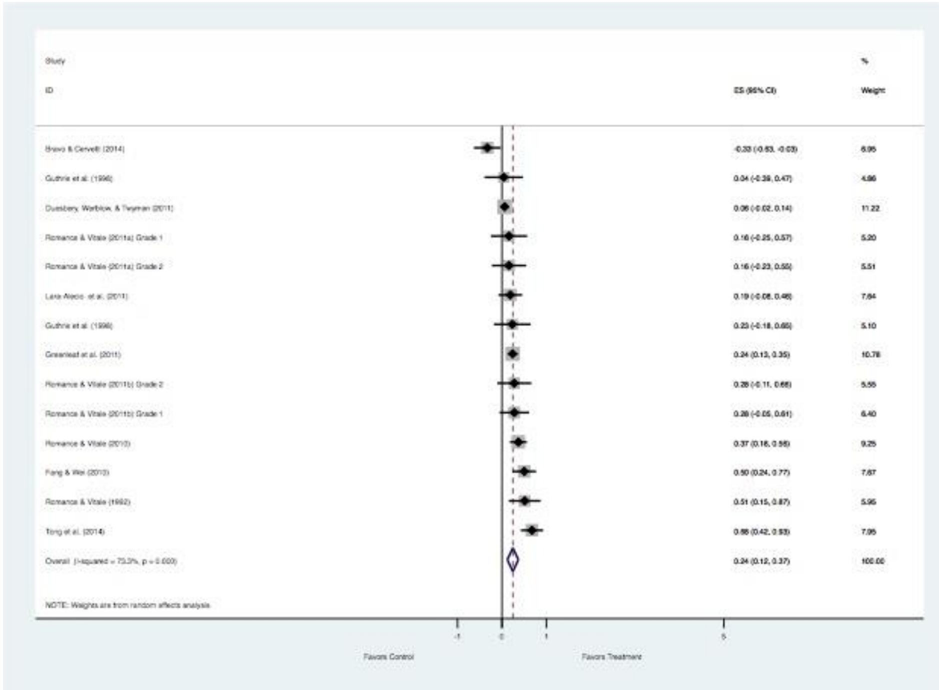


Figure 3. Forest Plot of Literacy Effect Sizes.

Moderator Analysis

Given the large amount of variance among effect sizes across both the science and literacy outcomes, further analysis was appropriate to attempt to identify differences in studies that may be contributing to varied levels of effect. Meta-regression is a technique used to determine the relationship of a study's effect size with particular covariates (Thompson & Higgins, 2002). It categorizes the between-studies variance into the amount explained by a study-level variable compared to the amount still unexplained using the R^2 statistic (Borenstein, Hedges, Higgins, & Rothstein, 2011). Additional recommendations for meta-regression indicate that while there are no definitive guidelines for the ratio of effect sizes to moderators, one moderator per ten effect sizes is reasonable, and to avoid false conclusions, moderators should be identified *a priori*. Based on analysis of variables least correlated with each other, a review of related literature, and the intent of this meta-analysis, the following 4 moderators were chosen for exploration in the meta-regression: 1) concept mapping, 2) ongoing professional development, 3) hands-on activities, and 4) use of a content-area reading or disciplinary-based literacy approach.

To first control for confounding participant variables, zero-order correlations were determined for potentially confounding participant and measurement variables, including socio-economic status, reading ability, grade level, and type of measure (see Table 8). For science, grade level (3-5 and 6-8), duration, and measure type, though not statistically significant, were sufficiently correlated with effect size, $\beta > .15$ (Lipsey & Wilson, 2001), and therefore were controlled by including in subsequent analyses. For literacy, SES, reading ability, grade level (6-8), and duration, and measure type were correlated with effect size and controlled in regression analyses.

Table 8

Zero-order correlations for study variables and effect size, science (k = 36) and literacy (k = 14)

Participant Variable	***β*** **Science**	***β*** **Literacy**
Socioeconomic Status	-.095	.159*
Reading Ability	-.107	.329*
Grade K-2	-.064	-.059
Grade 3-5	-.555*	-.107
Grade 6-8	.630*	.310*
Grade 9-12	.028	.000
Duration	-.351*	.274*
Standardized Measure	-.649*	.648*

Note. Socioeconomic status (1 = average, 0 = low); Reading Ability (1 = average, 0 = low); Grade Levels (1 = yes); Duration (1 = year-long); Standardized Measure (1 = yes); * indicates variable included in subsequent analysis to control for association with effect size, $\beta > .15$

Science Outcomes Meta-Regression Analysis. Random effects regression was conducted on the four identified variables separately (while controlling for the previously mentioned variables), to determine the relationship of each with effect size without the influence of other study characteristics. See Table 9 for full results. No moderator variables were of statistical significance when controlling for potentially confounding variables. However, concept mapping, professional development, and inclusion of hands-on activities were both negatively associated, indicating a slightly lower effect size in studies with these features. The use of a content-area reading approach, however, was positively correlated with effect size.

Table 9

Meta-Regression Results for Science Outcomes (k = 36), Controlling for Correlated Variables

Moderator Variable	***β***	**SE**	**Lower Limit**	**Upper Limit**	***p***
Concept Mapping	-0.24	.475	-1.21	0.73	.62
Hands-on Activities	-0.25	.460	-1.18	0.69	.59
Content-Area Reading Approach	0.58	.532	-0.34	1.50	.21
Ongoing Professional Development	-0.73	.561	-0.19	0.42	.20

Note. Concept Mapping (1 = yes, 0 = no); Hands-on Activities (1 = yes, 0 = no); Content-Area Reading Approach (1 = yes)

Literacy Outcomes Meta-Regression Analysis. Similar to the science meta-regression analysis, the four variables of interest were first entered separately while controlling for the five correlated variables of socioeconomic status, reading ability, grade level, duration, and measure type. Results showed that beyond these factors, ongoing professional development approached statistical significance (p = .08) and was positively associated with effect size. Use of a content-area reading approach was not statistically significant but did positively correlate with effect size. See Table 10 for results.

Table 10

Meta-Regression Results for Literacy Outcomes (k = 14), Controlling for Correlated Variables

Moderator Variable	***β***	**SE**	**Lower Limit**	**Upper Limit**	***p***
Concept Mapping	-1.09	.113	-0.38	0.16	.36
Hands-On Activities	0.20	.192	-0.25	0.66	.33
Ongoing Professional Development	0.47	.235	-0.09	1.03	.08
Content-Area Reading Approach	0.20	.147	-0.25	0.66	.33

Note. Ongoing Professional Development (1 = yes); Content-Area Reading Approach (1 = yes)

Instructional Variables: Summary Effects

Due to the exploratory nature of this meta-analysis and the number of effect sizes available for analysis (resulting in too few degrees of freedom to include all variables in the meta-regression), additional moderator variables that were coded were summarized to produce a single effect size for each characteristic. Note that these summary effects are not intended for comparison between studies with these characteristics and do not take into consideration moderating factors, but rather as descriptive data that may inform future research. Table 11 presents the summary effect size for each additional variable, along with its Q value (test for heterogeneity between and within studies having that characteristic), its 95% confidence interval as a measure of precision (95% of the time, the true effect will be within this range) and the z value (to indicate if the effect size was statistically significantly different from 0).

Table 11
Summary Effects of Additional Instructional Characteristics by Variable

Variable	***N***	***ES***	**95% CI**		***Q***	***z***
Science Outcomes (*k* = 36)			Lower	Upper		
Metacognitive Strategy	10	.958	.573	1.343	88.62*	4.87*
Student Discussion	25	.891	.638	1.143	435.23*	6.91*
Vocabulary Instruction	13	1.004	.607	1.402	403.02*	4.96*
Literacy Outcomes (*k* = 14)						
Metacognitive Strategy	3	.228	.123	.333	.77	4.26*
Student Discussion	12	.231	.094	.368	45.07*	3.31*
Vocabulary Instruction	6	.224	.021	.426	39.85*	2.17*

*Statistically significant, $p = .05$.

Publication Bias

Estimates of mean effect sizes in meta-analysis may be biased due to small sample sizes. Egger et al. (1997) found that often, the conclusions of meta-analysis that synthesize results of small studies may be later invalidated by more precise studies with larger sample sizes; therefore, it is important to consider such publication bias when interpreting results. Also, studies with negative results are less likely to be published, resulting in a potentially biased sample of studies. One way to check for publication bias is through visual inspection of a funnel plot that plots the effect estimate against the standard error. In a normal funnel plot, small studies will be grouped more tightly at the bottom, with larger studies spread at the top, resembling an inverted funnel. Additionally, the Egger's statistic provides a test for asymmetry of the funnel plot using a linear regression approach in which the effect size divided by its standard error is regressed against the inverse of the standard error.

Science Outcomes. A plot of studies included in the science effect size analysis showed that several fell outside the range of what would be predicted by sampling error by having larger than expected effects (see Figure 4). For the analysis of science outcomes, the Egger statistic was significant ($p < .01$), indicating the null hypothesis—that no small-study effects existed—should be rejected. This means some of the smaller studies in this analysis have effects that are systematically different than those of larger studies. However, one caveat in interpretation is that the Egger's value as a measure of heterogeneity may be limited in its statistical power when the analysis has a small number of studies (Egger et al., 1997).

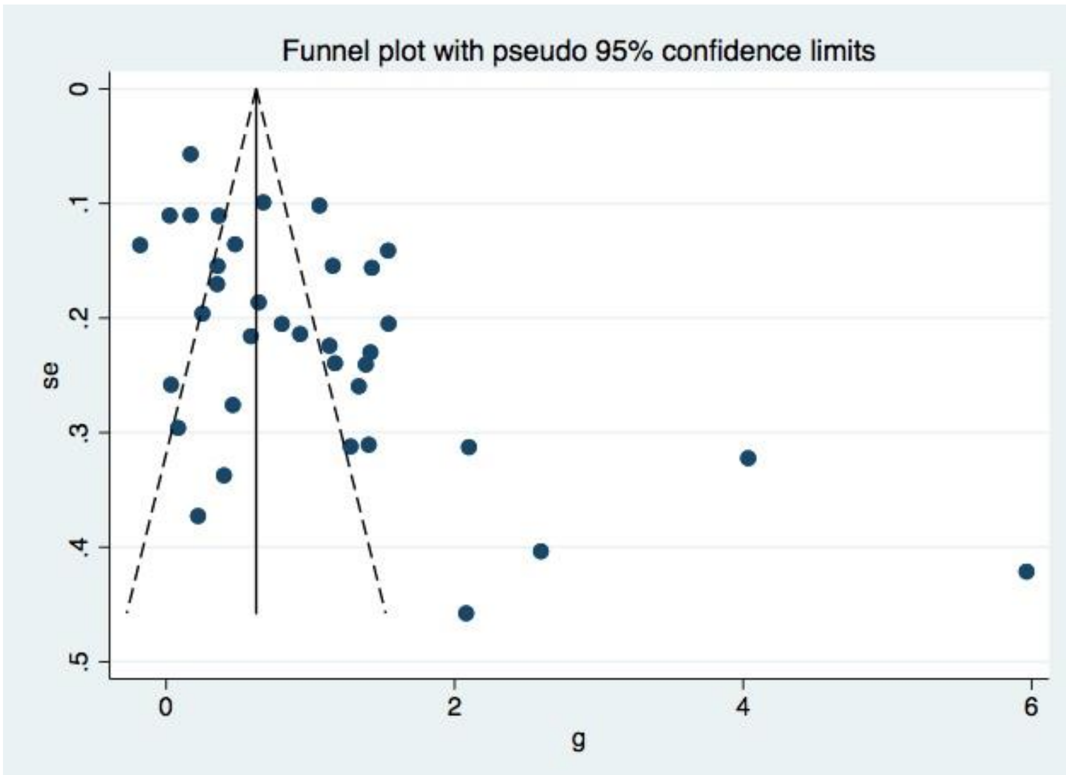


Figure 4. Funnel Plot for Science Outcomes.

One way to address publication bias is to implement the trim-and-fill method, which adjusts the mean effect estimate as if the funnel plot were symmetrical, assuming publication bias is the sole reason for asymmetry in the plot (Palmer, Peters, Sutton, & Moreno, 2008). In applying this method, the addition of 12 estimated unpublished studies within a random effects model produced an overall weighted mean effect of .47. This effect size is still of substantive importance (What Works Clearinghouse, 2017) and statistically significant from zero ($p < .01$).

Literacy Outcomes. Visual inspection of the funnel plot for literacy outcomes showed a more symmetrical representation of studies (see Figure 5). The Egger's coefficient for literacy outcomes was not statistically significant (p = .267), confirming the null hypothesis that no small-study effects existed.

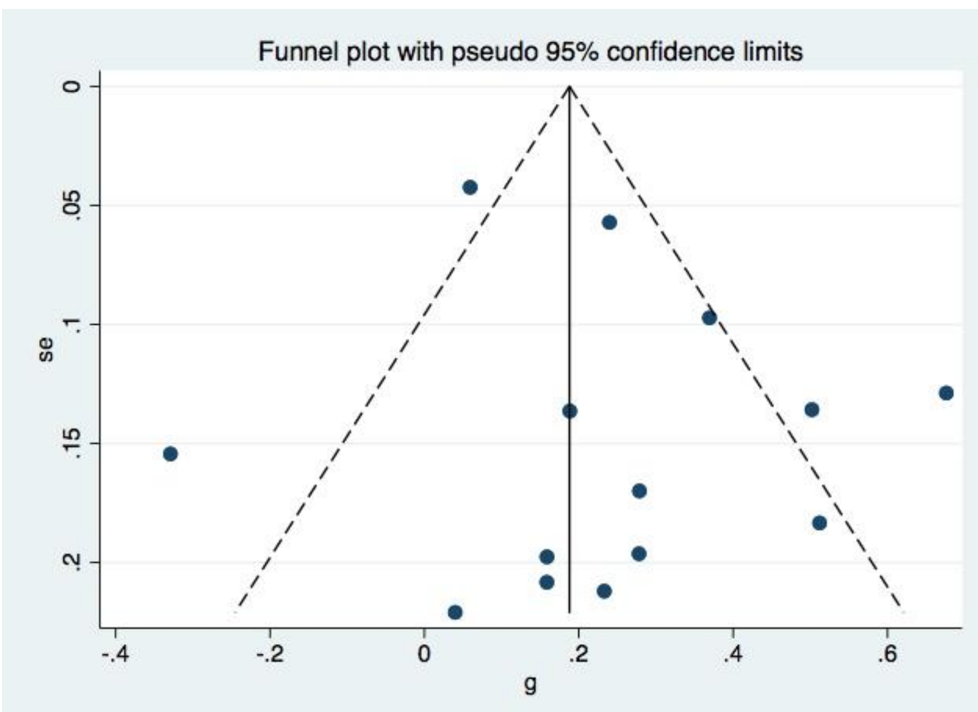


Figure 5. Funnel Plot for Literacy Outcomes.

Discussion

Overall mean effects indicate the integration of science and literacy is effective for the learning of science content, as measured by researcher-created or standardized measures. Additionally, the overall effect for literacy measures indicated the integration of science and literacy is somewhat effective.

Outcome Measures

It is important to consider the type of assessment used when interpreting the results of this analysis. The correlation of science measure type and effect size demonstrates that researcher-created measures were associated with higher effect sizes. One possible explanation is that, as found in previous meta-analyses (Scammacca et al., 2007), researcher-created measures tend to be more aligned with the intervention, and therefore result in higher effect sizes. In this analysis, many of the standardized measures were state-mandated tests at the end of the school year with questions covering the entire curriculum of a grade level. It is reasonable that students would produce better scores on measures that are, a) focused on a singular topic learned, and b) more immediate to the intervention. Interestingly, the results for literacy were opposite and unexpected, showing a higher association with standardized measures. Only 4 of the 14 effect sizes for literacy were derived from researcher-created measures, and of those, 3 identified the population as below-average readers. It could simply be that, for a struggling reader, the literacy element of the interventions was not enough to overcome word reading difficulties. For example, in an included study by Bravo and Cervetti (2014), the science content assessment was read aloud to control for word-reading difficulties, but the researcher-created reading assessment was not. The idea that students struggling at the word-level may need more direct and explicit instruction to overcome reading difficulties aligns with research mentioned previously (i.e., Kamil et al., 2008; Swanson, 1999).

Professional Development

Beyond participant or methodological characteristics, the moderator variable closest to statistical significance and with the strongest association to effect size was ongoing professional development for literacy outcomes. This finding supports what repeatedly appeared across included studies and in other related literature—that science teachers need ongoing support to implement integrated literacy instruction. Studies implementing ongoing professional development did so by meeting with teachers on a regular basis to clarify questions, improve delivery of interventions, and model methods of teaching specific strategies. Interestingly, ongoing professional development had a slight negative association with effect size for science outcomes. Though not enough to be statistically significant, it is possible that an ongoing emphasis on literacy practices for teachers with less support for teaching science content influenced students' science learning. Other research may pursue an ideal professional development program to advance both science content and related literacy practices.

Instructional Approaches

That hands-on activities had a slight negative association with effect size for science outcomes does not suggest that hands-on activities are unnecessary or should be excluded from science instruction. If anything, based on the overall weighted mean effect and that 64% of studies in the analysis included hands-on science instruction, this indicates that hands-on experiences in science are part of a practice that is positive for outcomes of science learning; however, it also indicates science content learning can happen in the absence of hands-on activities if the instruction is well-designed and includes textual support necessary for in-depth inquiry learning (Greenleaf et al., 2011). Hands-on activities were positively associated with reading comprehension outcomes, support for research that has suggested such activities bolster engagement and motivation for reading (Guthrie & Alao, 1997).

Studies using concept mapping had slightly lower effect sizes for science and literacy outcomes, though again, not statistically significantly so. One possible explanation for future consideration is that concept mapping techniques varied—in some, students were part of the mapping process, and in others, teachers provided parts of the map for students to complete. Whether a teacher guided the map or students generated the map may be related to the outcome and level of depth at which students were able to comprehend.

Use of a content-area or disciplinary-based approach was not statistically significant, however, a content-area approach was associated with positive effect size for both science outcomes and literacy outcomes. Though a great deal more research is necessary to substantiate any claim about these approaches, this analysis is an initial confirmation that the approach must be selected with the reader and end goal in mind. For example, science outcomes used in this meta-analysis asked students to produce science content knowledge. It could be that increased focus on the content via text-based instruction—through either approach—facilitated content acquisition. Additional science instruction occurred (i.e., text was not the sole vehicle of content delivery), so if an integrated model seeks to simply deepen content knowledge, it could be accomplished in a variety of ways through text. For struggling readers, content-area reading strategies may provide improved access to text, and that boost is enough to simultaneously improve content learning. However, more research is needed to determine which approach supports a variety of end-goals, such as in-depth, conceptual understandings of science beyond literal content knowledge. For example, some science assessments ask students to transfer knowledge to novel situations and make and evaluate scientific decisions based on existing knowledge—those assessments were not included in this analysis, and it is reasonable to suspect a different instructional approach may be required to produce gains on them.

Limitations of this Study and Recommendations for Future Research

Thompson and Higgins (2002) give several limitations of meta-analysis that are relevant to this research, including few numbers of studies or information not reported in studies. The integration of science and literacy is a relatively new line of research. The publication year of the earliest study included is 1988, with the majority of studies occurring from 2010-present. This meta-analysis serves to summarize extant research as a catalyst for more in-depth study of the integration of science and literacy. Results of the moderator analysis and summary effects may add to the existing research base and inform studies that will experimentally determine the effect of specific study characteristics.

Based on the limitations of this analysis, future research should consider including measures of reading comprehension in studies of integration to better determine the effect on reading comprehension for all types of readers. No studies conducted a direct comparison of content-area reading strategies and disciplinary literacy strategies; as disciplinary literacy becomes more mainstream in national and state curriculum initiatives, empirical research to determine its effect on both science learning and literacy is necessary.

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CHAPTER IV

DISCUSSION

Spiro (1980) describes comprehension as a process of taking the skeletal representation of language and enriching it with one's own knowledge to construct meaning. This research was conducted to explore the relationship of reading comprehension strategies and the acquisition of knowledge so that both comprehension and knowledge may be improved. Important conclusions can be drawn from both studies, as follows.

Both studies demonstrate that content can be learned effectively in the context of reading instruction. In study one, students in the literal and inferential conditions learned the content effectively when taught through reading strategy instruction. Whether the strategy instruction or the additional content knowledge made the difference on the near-transfer measure of comprehension is unclear, but comprehension gains were evident as compared to a business-as-usual control group. In study two, overall weighted mean effects show, by Cohen's (1977) general guidelines, a large effect for science content learned that happened in the context of reading instruction. When controlling for participant and methodological variables and comparing studies that used a content-area approach or a disciplinary literacy approach, there was no statistically significant difference—the method then, in these studies, was not associated with effect size. It could be hypothesized that, in alignment with the work of Wilkinson & Son (2011), both studies demonstrated that an increased, in-depth focus on text aligned with content instruction made a difference beyond any one specific strategy.

Ongoing professional development for content-area teachers is important. Study one was taught by trained doctoral students who received ongoing support throughout the intervention period. In study two, ongoing professional development was statistically significantly associated with higher effect sizes on literacy outcomes. Both studies confirm the need to support instruction not only with professional development on evidence-based methods that can be generalized to all instruction, but also with specific, real-time support that can refine practice. Implications for schools include: 1) considerations for additional collaborative planning time for teachers implementing these models of instruction, and 2) the availability of instructional coaches or teacher-leaders who are well-versed in the practices of integrating literacy instruction into the content areas and vice versa.

The studies presented in this dissertation contribute to the literature in several ways. Study one supports findings in earlier research that comprehension strategy instruction is effective, particularly on near-transfer measures of comprehension. Additionally, it provides information on a specific sample of readers—the study concluded that inference strategy instruction may not be needed for students with average to above-average comprehension, as content knowledge instruction was similarly effective for improving comprehension. It also supports findings from other research that a content learning approach can improve comprehension (McKeown, Beck, Sinatra, & Loxterman, 1991). Study two summarizes findings from studies on the integration of literacy and science; the overall weighted mean effect shows promise for the practice overall, and provides direction for future research in corroborating the most effective components of integrated science and literacy instruction.

Central to both studies is the role of background knowledge in reading comprehension. Reading comprehension theory explains how the lack of background knowledge may contribute to problems in adolescent reading (i.e., Kintsch, 1998; Cromley & Azevedo, 1997); what the reader brings to the text is of critical importance to fill in the gaps. However, a multitude of studies have also demonstrated the importance of reading strategy instruction, particularly for poor comprehenders (Kamil et al., 2008; NRP, 2000; Swanson, 1999); therefore, instruction is also of critical importance if students are to become capable readers who use strategies fluidly and with automaticity. The challenge addressed in the studies presented here is how to achieve both simultaneously—the development of background knowledge and the appropriate amount and type of instruction to improve reading comprehension. The findings of both studies support that content knowledge and reading strategies can be taught and learned concurrently; however, approaches to doing so are varied and more research is needed to determine the appropriate balance of content and strategy instruction.

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