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Reading Strategies for Secondary Science Teachers

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Abstract

This paper concerns reading strategies for secondary science teachers, including a review of pertinent standards, scholarly literature regarding implementation and associated challenges, and presentation of original data of strategy use. Survey results suggest that the three types of literacy strategies explored (direct reading instruction, vocabulary builders, and concept organizers) are being used in the secondary science classroom, but to varying and limited degrees, and that teachers' relative perception of the importance of implementing these literacy practices may not predict their actual implementation. Based on these findings, we propose means to assist science students in meeting the upcoming reading demands.

Introduction

Over the next few years most districts in the United States will be required to adopt and implement the Common Core State Standards (CCSS) (CCI, 2013a) and Next Generation Science Standards (NGSS) (NGSS, 2013a). CCSS for English indicate college and career ready students can read complex texts, both in traditional fiction and nonfiction English classroom texts and discipline-specific texts (CCI, 2013b). NGSS requires students' engagement in science practices that are argued to increase student language demands along with science content. The new science standards are built on research that suggests both science and language learning improve when students are asked to apply language skills in disciplinary context, such as the science classroom (Greenleaf et al., 2011; Lee, Quinn, & Valdés, 2013; Pearson, Moje, & Greenleaf, 2010).

The enhanced focus on literacy skills development within the context of science teaching and learning is well founded. While there are similarities in reading among all academic disciplines, each content-area assumes specific knowledge on how to acquire relevant information from texts. Reading in content-areas generally differ in text structure and content specific vocabulary. In science, texts serve as a product of past research and assist others in interpreting and thinking about natural phenomena. A scientist uses information in texts to develop new research questions and to design experiments (Lemke, 2004; Pearson, et al., 2010). Towards achieving goals of better student understanding of, and engagement in the practices of science, students must become skillful in reading, understanding, and writing scientific texts.

We begin this paper with a review of the Common Core State Standards and Next Generation Science Standards, both of which arguably raise the language demands in secondary science classrooms. We then review the literature on literacy strategies for the science classroom. We document the tools/techniques a small sample of secondary science teachers use in the classroom. Then, in an effort towards fostering teachers' enhanced commitment and abilities to enact key literacy strategies, we propose means to assist science students in meeting the upcoming reading demands.

Key Terms

We define some key terms. First, language is the communication of ideas through a system of signals that could be spoken, gestured or written ("The free dictionary: language ", 2014). Second, language demands and literacy are used interchangeably throughout the paper and we define both as the level of sophisticated language and skills, such as analysis and argumentation, necessary to successfully communicate. Third, literacy strategies are the tools and techniques implemented by a teacher and used by students to improve their language. Fourth, it is important to note that throughout the paper the terms reading and reading demands are used interchangeably as we define both as obtaining meaning from written work.

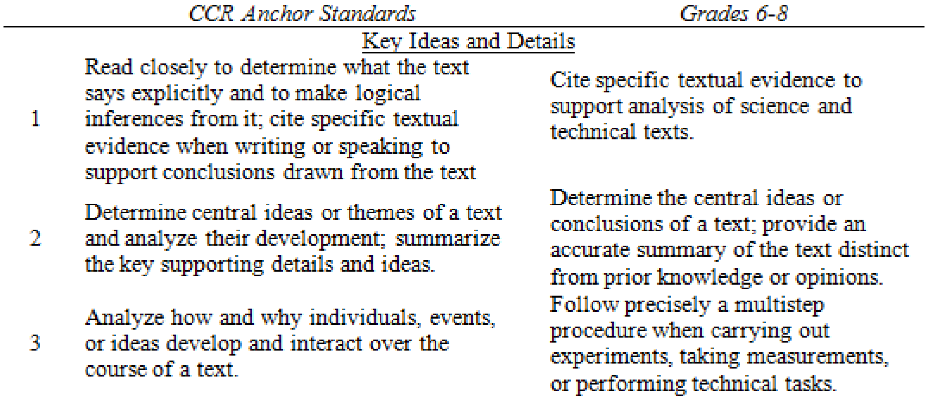
Literature Review

Common Core State Standards

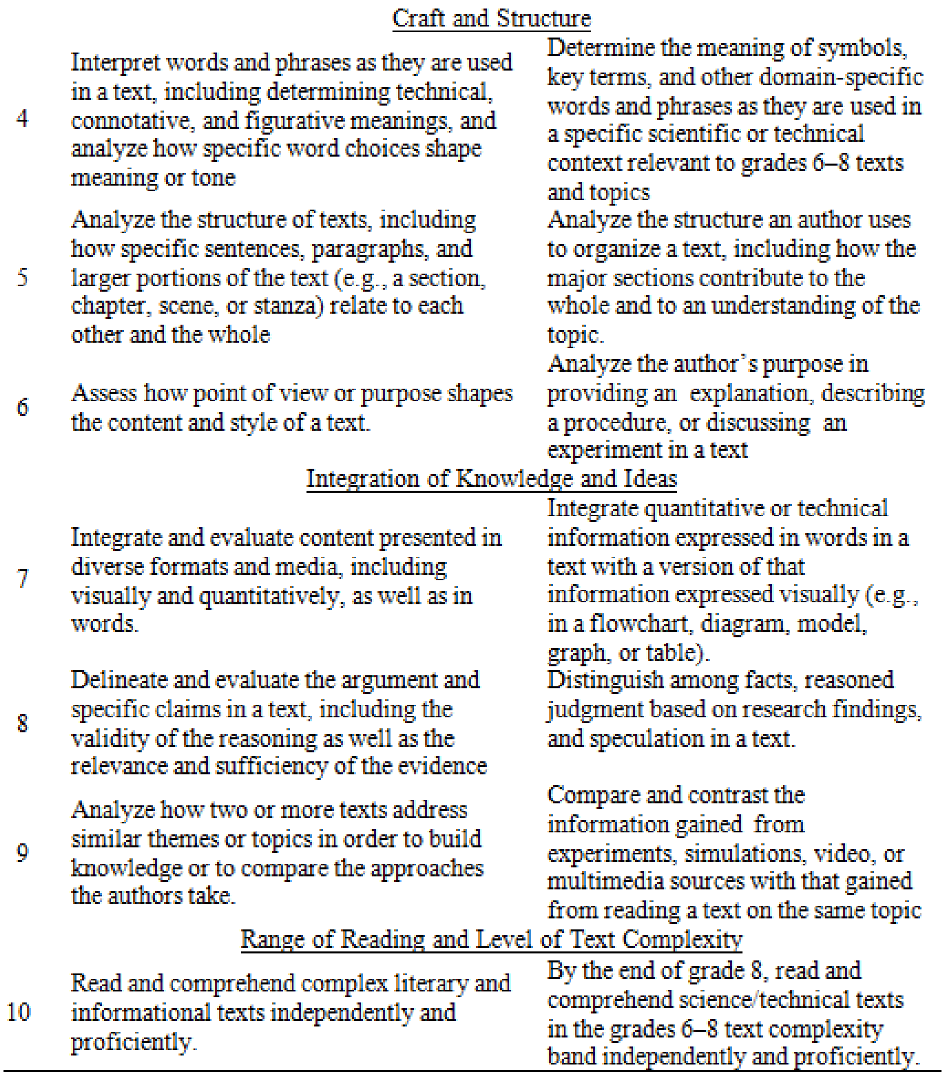
The CCSS, released in 2010, outline new standards in both Math and English Language Arts (CCI, 2013a; Porter, McMaken, Hwang, & Yang, 2011). The new English standards include increased emphasis in reading discipline-specific informational texts. The increased emphasis on informational texts mean that reading instruction must occur outside the traditional English Language Arts (ELA) classroom, "Because the ELA classroom must focus on literature (stories, drama, and poetry) as well as literary nonfiction, a great deal of informational reading in grades 6–12 must take place in other classes…" (National Governors Association, 2010, p. 5). This calls for an instructional change in science as traditionally, reading instruction is not included in the secondary science curriculum.

Common Core State Standards outline ten reading standards for science and technical texts in each grade span. These standards relate to the broader College and Career Readiness (CCR) anchor standards (CCI, 2013c) (See Table 1). The CCR, coupled with grade specific standards, clearly articulate student content-based literacy understanding and capabilities for the end of each grade span (CCI, 2013a). For example, Science and Technical Texts Standard 4, states that student should "determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics" (National Governors Association, 2010, p. 62). This means that students will be held accountable for deciphering and interpreting meaning from content specific texts. For example, a biology text may include words like carnivore, herbivore, omnivore, autotroph, and heterotroph. If a teacher helps students understand roots such as -ivore or -troph common in science, then students can apply these to decipher new terms. CCSS implementation means that science teachers need to explicitly integrate reading strategies, such as these, into their classrooms to assist students in meeting the new standards.

Table 1. CCR anchor standards and their corresponding science and technical texts standards for grades 6-8.



	CCR Anchor Standards	*Grades 6-8*
	Key Ideas and Details	
1	Read closely to determine what the text says explicitly and to make logical inferences from it; cite specific textual evidence when writing or speaking to support conclusions drawn from the text	Cite specific textual evidence to support analysis of science and technical texts.
2	Determine central ideas or themes of a text and analyze their development; summarize the key supporting details and ideas.	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
3	Analyze how and why individuals, events, or ideas develop and interact over the course of a text.	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

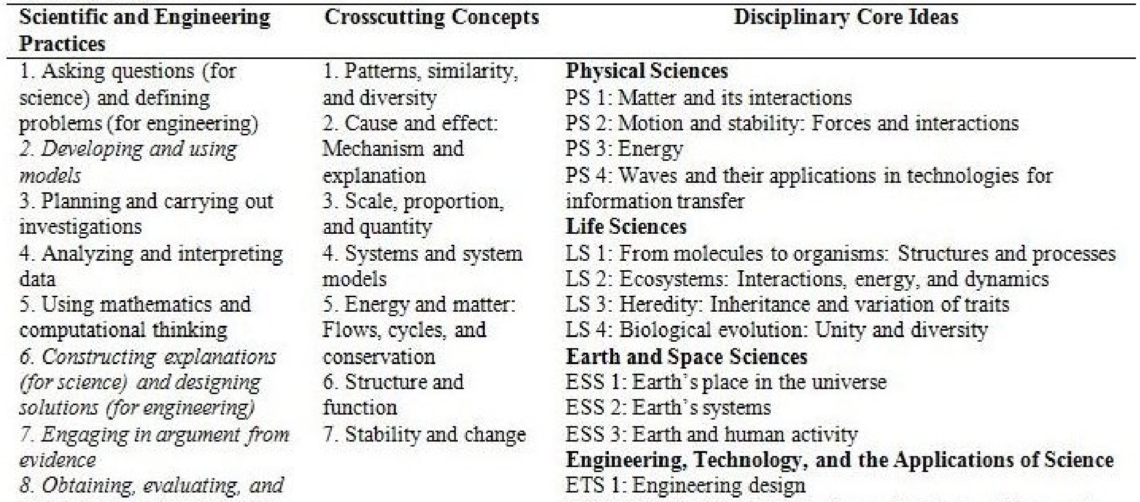


	Craft and Structure	
4	Interpret words and phrases as they are used in a text, including determining technical, connotative, and figurative meanings, and analyze how specific word choices shape meaning or tone	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics
5	Analyze the structure of texts, including how specific sentences, paragraphs, and larger portions of the text (e.g., a section, chapter, scene, or stanza) relate to each other and the whole	Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.
6	Assess how point of view or purpose shapes the content and style of a text.	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text
	Integration of Knowledge and Ideas	
7	Integrate and evaluate content presented in diverse formats and media, including visually and quantitatively, as well as in words.	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
8	Delineate and evaluate the argument and specific claims in a text, including the validity of the reasoning as well as the relevance and sufficiency of the evidence	Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
9	Analyze how two or more texts address similar themes or topics in order to build knowledge or to compare the approaches the authors take.	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic
	Range of Reading and Level of Text Complexity	
10	Read and comprehend complex literary and informational texts independently and proficiently.	By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

Next Generation Science Standards

Next Generation Science Standards, released in April 2013, outline new standards for science education in the K-12 classroom (O.D.E., 2014). NGSS is organized by scientific and engineering practices, crosscutting concepts, and disciplinary core ideas (See Table 2). Scientific and engineering practices, crosscutting concepts and disciplinary core ideas provide a foundation for student performance expectations. These performance expectations build on one another across grade levels to outline a comprehensive K-12 science education framework (NGSS, 2013c). Of the eight science and engineering practices that define inquiry for science classroom practices, Hakuta, et al. (2013) and Lee, et al. (2013) identified four as language-intensive, sense-making practices; see italicized text in Table2. The language-intensive practices build on one another, and will increase both the sense-making and language demands of students in the science classroom. For example, students are required to read, write, and represent their thinking as they develop models and explanations for natural phenomenon.

Table 2. Three Dimensions of the Next Generation Science Framework. Language intensive sense making practices are *italicized.*



Scientific and Engineering Practices	Crosscutting Concepts	Disciplinary Core Ideas
1. Asking questions (for science) and defining problems (for engineering) *2. Developing and using models* 3. Planning and carrying out investigations 4. Analyzing and interpreting data 5. Using mathematics and computational thinking *6. Constructing explanations (for science) and designing solutions (for engineering)* *7. Engaging in argument from evidence* *8. Obtaining, evaluating, and communicating information*	1. Patterns, similarity, and diversity 2. Cause and effect: Mechanism and explanation 3. Scale, proportion, and quantity 4. Systems and system models 5. Energy and matter: Flows, cycles, and conservation 6. Structure and function 7. Stability and change	**Physical Sciences** PS 1: Matter and its interactions PS 2: Motion and stability: Forces and interactions PS 3: Energy PS 4: Waves and their applications in technologies for information transfer **Life Sciences** LS 1: From molecules to organisms: Structures and processes LS 2: Ecosystems: Interactions, energy, and dynamics LS 3: Heredity: Inheritance and variation of traits LS 4: Biological evolution: Unity and diversity **Earth and Space Sciences** ESS 1: Earth's place in the universe ESS 2: Earth's systems ESS 3: Earth and human activity **Engineering, Technology, and the Applications of Science** ETS 1: Engineering design ETS 2: Links among engineering, technology, science, and society

Note: Table modified from Lee, O., Quinn, H., & Valdés, G. (2013). Science and Language for English Language Learners in Relation to Next Generation Science Standards and with Implications for Common Core State Standards for English Language Arts and Mathematics. Educational Researcher, 42(4), 223-233.

The Intersect of Common Core State Standards and Next Generation Science Standards

Both the CCSS and NGSS documents aim to raise the academic rigor and cognitive demands experienced by all students in United States classrooms (NGSS, 2013b; CCI, 2013a). For instance, once primarily expected from talented and gifted students, the new science standards require all students to successfully use science and engineering practices and understand the interplay between crosscutting concepts and disciplinary core ideas (NGSS, 2013b). The new English language arts standards indicate that all students need to read complex discipline-specific texts, requiring an understanding of scientific norms including science semantics, evidence presentation, argumentation and evaluation of claims. In addition to requiring that students acquire information from content-area texts, both sets of standards ask students to obtain, synthesize, evaluate, and communicate evidence and other information, construct explanations, engage in argumentation from evidence. Not typical practices in the traditional science classroom, CCSS and NGSS raise the academic rigor and language demands of science classrooms (CCI, 2013; NGSS, 2013b; Lee, et al., 2013).

Integrating Primary Science and Reading

Traditionally, language instruction and content area instruction are separate isolated lessons (Greenleaf, et al., 2011; Snow, Met, & Genesee, 1989). However, a growing body of research supports teaching science and English literacy side-by-side at all grade levels. In the elementary setting, numerous studies outline the effectiveness of teaching science content and literacy simultaneously (Brown & Ryoo, 2008; Carrejo & Reinhartz, 2012; Guthrie & Cox, 2001; Zohar & Barzilai, 2013). For example, Carrejo & Reinhartz (2012) performed a mixed-methods study that included classroom observations and analysis of fifth grade state science and reading tests. They found that when language literacy (reading, writing, speaking and listening) was taught through the lens of science instruction English language learning (ELL) students made significant improvements in both science and reading test scores.

Teachers in this study used a 5E approach (engage, explore, explain, elaborate, and evaluate) to teach their students science and language literacy. One strategy used was vocabulary loops where each student was given a definition or science term, and then one student was asked to read a word out-loud, the student with the corresponding definition then read the definition out-loud. The loop was completed when all the science terms and definitions were matched.

Guthrie and Cox (2001) found that fifth grade students engaged in science content reading, supplemented from direct instruction from the teacher, improved significantly in both their science and reading scores in comparison to a control group, as evidenced via classroom observations and pre- and post-content and reading skills assessments. Students logged daily observations of the moon in a lunar log, posing questions about the changing size and shape of the moon. To investigate the phenomena, students read texts scaffolded for their reading abilities, but each reading was still conceptually complex scientifically. As such, teachers provided direct instruction on how to read them, explaining key features such as table of contents, index, captions, and diagrams. The teacher also modeled how to summarize texts by locating topic sentences and supporting information. The authors concluded that explicit reading instruction and extensive time spent reading (60+ hours) seeded students' motivation to read additional material related to the phenomenon. This contributed to their significant improvement in science and reading scores.

Integrating Secondary Science and Reading

Research shows that skillful reading at an early grade level may not transfer into discipline-specific literacy (Johnson, Semmelroth, Allison, & Fritsch, 2013; Lee & Spratley, 2010; Snow, 2010). Emphasis on reading instruction shifts when students reach secondary grades (6-12). In primary (K-5) education students are learning to read and explicit literacy strategies are employed. In 6-12 secondary education, students are expected to read to learn content specific information without explicit reading strategy instruction (Tong, Irby, Lara-Alecio, & Koch, 2014). But literacy skills become more demanding as students advance in a discipline, arguing for even more specialized content-based literacy support for secondary students (Greenleaf, et al., 2011; Lee & Spratley, 2010). While the literature emphasizes the need to improve adolescent literacy through content instruction (Faggella-Luby, Ware, & Capozzoli, 2009; Kamil, 2008; Moje, Overby, Tysvaer, & Morris, 2008; Shanahan & Shanahan, 2008; Stewart-Dore, 2013), few empirical studies measure the impact of literacy strategies in secondary education science classrooms (Greenleaf, et al., 2011; Wang & Herman, 2005). Moje et al. (2006) investigated the effectiveness of three different literacy strategies in the 7th grade science classroom. Data was collected through student and teacher interviews, classroom observations, pre and post assessment scores on science content and reading skills, and artifacts of student work. Experimental design included 3 control classrooms and 3 treatment classrooms in which literacy strategies were implemented, including definition maps, vocabulary concept cards, and list-group-label strategies. Used in conjunction with the science text, these strategies provided a guide for students to engage with their reading, increased student motivation to read, helped organize student thinking about the text, and provided teachers with a visual representation of student thinking.

At the high school level, Greenleaf, et al (2011), provided professional development opportunities aimed to improve high school biology teachers' ability to provide literacy instruction by active inquiry with science texts. Researchers implemented a group-randomized, experimental design in which treatment group teachers attended professional development sessions that emphasized reading strategies. Researchers collected data through pre- and postsurveys of teacher knowledge, beliefs, and science and literacy instructional practice, interviews after professional development, artifacts of teaching and student work, and pre- and post-student assessments of biology content and reading skills. At professional development sessions teachers learned to implement strategies around science reading, including think-alouds, think-write-pair-share, and small-group discussions. Think-alouds allowed students to verbally explore disciplinary questions before reading. Think-write-pair-share occurred after students engaged in the text and are focused on answering the disciplinary question. Small group discussions occurred after pair-sharing and were the context for students to record their observations and evidence to support a claim about a previously constructed question. Researchers found that students of teachers who participated in these professional development opportunities improved significantly more than control counterparts in both reading comprehension and biology content learning.

Challenges in Implementing Science Reading

While the Common Core State Standards, Next Generation Science Standards, and current research call for integrating discipline-specific reading instruction in the science classroom, it may be difficult for secondary science teachers to implement literacy strategies. Teaching towards both CCSS and NGSS calls for a large shift in K-12 science education. Since the educational system is complex and multifaceted, changes may need to occur in small incremental steps (Bybee, 2014). More specifically, teachers' resistance to integrating literacy strategies in content classrooms may stem from school culture, and the thought that reading instruction takes time away from instruction towards a content learning goal (O'Brien, Stewart, & Moje, 1995). Additionally, pressure to teach a wide breadth of content in an efficient manner may translate to a limited repertoire of content-area teaching practices and the notion that helping students improve their reading is not their purview (Cantrell, Burns, & Callaway, 2009; Moje, 2006; Stewart-Dore, 2013). Other teachers may wish to assist students with discipline-specific reading, but feel they lack tools and strategies necessary to meet their students' needs (Hall, 2005; Murnane Sawhill, & Snow, 2012). Consequently, teachers can value reading in their content area classes, but hold deficits in expertise, preparation and ability to actively and successfully attend to their students' reading needs (Greenleaf, Schoenbach, Cziko, & Mueller, 2001).

Professional development opportunities may help to alleviate these heartfelt constraints. A recent study noted that teachers felt they gained valuable knowledge and improved their confidence in teaching content-relevant reading after a professional development experience (Fine, Zygouris-Coe, Senokossoff, & Fang, 2011). During a four-day professional development opportunity, teachers read and discussed articles on content area reading strategies as well as ways to implement these strategies in the classroom. The researchers found that when teachers were armed with these teaching strategies they felt more prepared and expressed confidence in their ability to implement the strategies. While building teachers' confidence regarding use of specific tools and strategies seems promising towards alleviating anxiety associated with content-area reading instruction, a limitation of this research is the lack of follow-up to ascertain the impact of the professional development on actual teacher practice.

Strategies of the Science Classroom

The above sections of this paper have noted potential strategies to incorporate content area reading instruction into the science classroom. These literacy strategies can be organized into three main categories: direct reading instruction where students are explicitly taught how to read content area texts; vocabulary builders, where activities are developed to assist students in building content specific vocabulary; and concept organizers, where students use tools to arrange concepts and terms found in the reading while inquiring about a phenomenon through text.

The authors maintain that these literacy strategies can be classified into a three tier system (see Figure 1). Teaching direct reading strategies help students initially access information in texts (tier one). Vocabulary builders help to build language and terminology found in the texts (tier two). Concept organizers facilitate students in making connections between and across concepts (tier three). We contend that the tiers naturally "build on one another," in terms of allowing students to scaffold understanding of scientific texts. We hypothesize that when one tier is missing, students may struggle in developing a coherent understanding of content specific texts and, thus, argue that it is important for teachers to implement all three tiers of literacy strategies in their science classroom. Implementing these three tiers of literacy strategies will help all students access content found in scientific texts.

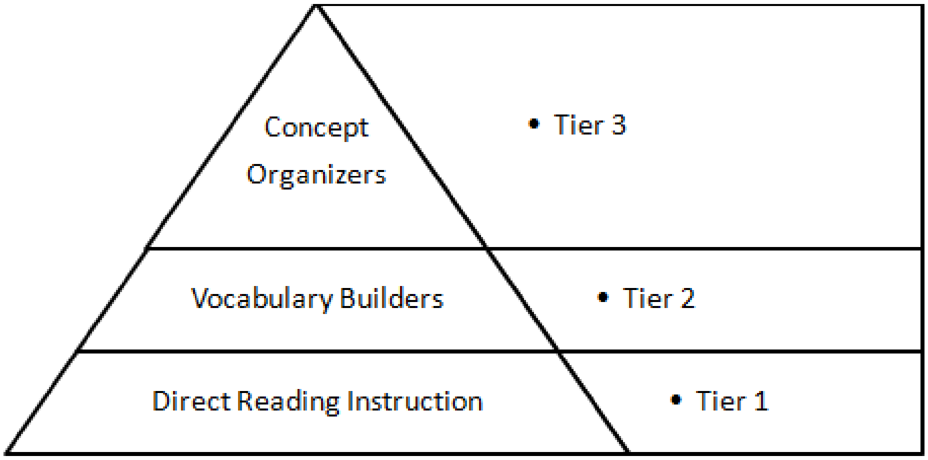


Figure 1. Three tiers of literacy strategies. Each tier builds upon the last, working towards meeting the language demands of the CCSS and NGSS.

Reading in the Science Classroom Survey

Based on this rationale, we developed two queries. First, what is the current state-of-the-art in secondary science teacher practices? Second, what was their felt efficacy regarding implementing key literacy strategies? In the spring of 2014 we conducted an online survey to further investigate secondary science teachers' views on literacy strategies in the science classroom, their perceived preparedness to meet literacy requirements in the standards documents, and the frequency that the three tiers of literacy strategies are used in the science classroom. Secondary science teachers were identified from local area middle and high schools and 145 were notified of the survey through a direct email. The email gave a brief survey overview and a web link to access the online survey. After two reminder emails the survey was closed with 53 participants, correlating to a 36% response rate. Of those responding, 37% (n=20/53) taught middle school (grades 6-8) and 63% (n=33/53) taught high school (grades 9-12). Survey data was imported into the SPSS statistical package for data analysis. Cronbach's alpha (α=0.736) was run and the internal reliability for the 12 survey items was deemed acceptable. Mann-Whitney U analysis was utilized to compare survey items for statistical significance. Due to the online nature of the survey, only teachers whose email address could be located were asked to participate.

Reading Importance and Frequency

Forty-nine percent of survey respondents (n=26/53) thought that it is 'extremely important' for 'students to obtain science information from written sources' while 47% (n= 25/53) found it 'somewhat important.' Forty seven percent (n=25/53) of survey respondents reported that it is 'somewhat important' for 'students to receive instruction on how to read science specific texts' while 46% (n=24/53) reported that it was 'extremely important'.

Forty-three (n= 23/53) percent of teachers surveyed reported that they assign reading in their classroom once per week or more. The most commonly used reading instruction was vocabulary builders with 57% (30/53) of teachers reporting that they use vocabulary builders once per week or more. The second most used reading strategy was concept organizers with 32% (n=17/53) of teachers reporting that they use concept organizers once per week or more. The least frequently used reading strategy was direct reading instruction with only 17% (n=9/53) of teachers reporting that they use direct reading instruction once per week or more.

Interestingly, there was no significant difference between teachers' perceived importance of students receiving reading instruction and their use of direct reading instruction, vocabulary builders, or concept organizers (Mann-Whitney U=236.5 z=-1.31 p== 0.190, Mann-Whitney U=210.5 z=-1.842 p=0.068, and Mann-Whitney U=233 z=-1.131 p=0.258 respectfully). Thus, teachers who perceived that reading instruction is highly important did not use direct reading instruction, vocabulary builders or concept organizers significantly more often than those teachers indicating reading instruction to be less important.

Middle School vs. High School

Survey results indicated that middle school science teachers provide direct reading instruction significantly more often than high school teachers (Mann-Whitney U=192 z=-2.511 p= 0.012). Yet, no significant difference was found between middle and high school teachers in relationship to frequency of using vocabulary builders and concept organizers in their classroom (Mann-Whitney U=310 z=-0.246 p= 0.806 and Mann-Whitney U=246 z=-1.173 p= 0.241, respectfully).

Implications

Given our review of pertinent standards, scholarly literature, and our survey findings, we offer the following implications. Survey results suggest that the three types of literacy strategies explored (direct reading instruction, vocabulary builders, and concept organizers) are being used in the secondary science classroom, but to varying and limited degrees. Overall, vocabulary builders were the most commonly used strategy. This is consistent with the perspective that science has discipline specific vocabulary (Lemke, 1990; Lemke, 2004; Pearson, et al., 2010) and thus, teachers need to assist students in developing scientific vocabulary. Results, and the rationale underlying the new standards, indicate that most literacy strategies explored could be used more often. Of great importance may be the need to increase direct reading instruction. Survey results suggest that while most secondary science teachers feel that it is important for students to receive instruction on how to read science specific texts, teachers do not commonly provide direct reading instructions. While provided at the middle school level significantly more often than at the high school level, direct reading instruction was the lowest of the strategies claimed implemented across the sample. Thus, while special focus should attempt to remedy the general shift away from reading instruction that occurs during the upper secondary years (Lee & Spratley, 2010), all secondary teachers need to provide their students with initial access to the text through direct reading instruction. This provides the structure for moving up the three tiers of literacy strategies, ultimately allowing students access to the language of science through vocabulary builders towards helping them extract information from and make connections between science concepts found within written work.

Looking across the sample, we also note the interesting finding that teachers' relative perception of the importance of implementing these literacy practices in the classroom may not be predictive of their actual implementation of these practices. Towards meeting the critical need for specialized literacy support for content-area reading as students advance in their academic career (Greenleaf, et al., 2011; Lee & Spratley, 2010), professional development opportunities for teachers must move beyond fostering teachers' felt importance regarding these practices to significantly growing their commitment and ability to implement these literacy practices. This can only be done by professional developers cognizant of the felt constraints on the part of science educators, including the inability to envision science content-literacy development synergy and their fears (and associated reality) of being asked to teach curriculum and via instruction they have not been trained to enact. In addition, while the promise of professional development towards promoting educator efficacy in implementing literacy strategies has been noted (e.g. Fine et al., 2011), the field will benefit from empirical study of professional development opportunities' efficacy in helping teachers, at various points in their evolution regarding literacy strategies in the science classroom, actually implement these strategies effectively in their unique classrooms.

Conclusion

National standards call for the application of language skills in disciplinary context, arguably raising the language demands for secondary science students, and associated pedagogical demands of their teachers. A review of pertinent scholarly literature indicates that effective implementation of literacy strategies is limited and that professional development focused on remedying this situation may be impeded by felt constraints on the part of science educators. Our survey with a limited group of secondary educators indicated that three types of literacy strategies (direct reading instruction, vocabulary builders, and concept organizers) are known and being used in the secondary science classroom, but to varying and limited degrees, and that teachers' relative perception of the importance of implementing these literacy practices may not be predictive of their actual implementation. Based on these findings, we argue for individualized professional development opportunities for teachers that help them recognize the importance of these practices for student development, as well as significantly advance their commitment to and ability to implement these literacy practices. Perhaps most important is the need for inclusion of development concerning direct reading instruction in these professional development opportunities and how this focus, and means towards delivering it, is translated into effective secondary science teacher practice.

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