The Effectiveness of Reading Comprehension Strategies in High School Science Classrooms

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Abstract: Reading strategies have been shown to increase comprehension for younger learners. As students move to middle and high school, there is little opportunity to learn about, practice, and apply these strategies in classes, particularly in the content domains like science. Nonetheless, there is a growing national consensus that high school content area teachers need to better integrate discipline-specific reading supports throughout the curriculum. We evaluate the effectiveness of an effort to integrate reading comprehension strategies in biology classrooms. Students' independent proficiency with the strategies predicted science achievement, even when controlling for prior reading achievement. These results provide evidence that strategies are effective and practical in intact science classrooms. We discuss the implications of the findings for the design of content-area literacy instruction. Finally, we describe our efforts to refine the design of the strategy supports based on the empirical results.

Learning to Read and Reading to Learn

Reading is a complicated cognitive process that is likely the most important competency acquired in all of schooling. As students move from the early elementary years through high school and beyond, the focus changes from 'learning to read' to 'reading to learn.' Many middle and high school students fail to make this transition. That is, many students can decode individual words on a page but are unable to successfully comprehend the sentences and paragraphs that make up academic text. Based on an influential theoretical model of reading comprehension, we could say that these students are unable to build an adequate text base (direct representation of the semantic structures of text) and situational model (integrated reordering of text content with prior knowledge) (Kintsch, 1998), which represent readers' constructive understanding of the meaning of text. It is well known that American students struggle to read academic texts. About 70% of American eighth-grade students performed below the *proficient* level on the National Assessment of Educational Progress reading tests in 2003 (National Center for Educational Statistics, 2005). Students who struggle to read to learn remain at a disadvantage throughout school and later in life as more desired careers require workers to be able to independently read new material, integrate that material with existing models of understanding of a domain, and generate ideas from the new understanding. In the work described here, we detail an intervention that grew out of our multi-year effort to support high school science teachers as they work to increase students' disciplinary learning by focusing on targeted reading comprehension strategies that students use as they engage with high school science texts. We describe the reading comprehension strategies teachers and students used in intact high school biology classrooms, present some of the research base on the use of comprehension-building strategies with older students, and present a rationale for the embedding of reading comprehension strategies in content domains like science. We provide evidence of the effectiveness of the strategies based on performance of students on two assessments of science achievement. Finally, we take initial steps to revise the reading strategies based on the empirical findings. Our work is particularly congruent with the goals of the ICLS conference that stress how discipline-specific learning needs to be accounted for in effective learning interventions.

Reading Comprehension Strategies in Science

Contemporary models of reading stress that in order to derive meaning from text, readers rely on both text-driven and knowledge-driven processes (Goldman & Rakestraw, 2000) in which they make connections between elements in a text, their understanding of the text, and between the text and prior knowledge (Wittrock, 1990). A reader must actively construct understanding by integrating existing and new knowledge in part through the application of flexible strategies that help foster, monitor, regulate, and maintain comprehension (Alexander & Jetton, 2000). A number of studies have demonstrated that students' understanding of and memory for text can be strengthened through explicitly teaching students multiple comprehension strategies (Pressley, 2000). Some common reading strategies include paraphrasing, self-questioning, reflecting, marking structures of text, summarizing the gist of text, teaching others about a text, etc.

When learned well, strategies have been shown to increase comprehension. Even so, there is evidence that high schools rarely provide opportunities for students to learn and practice effective reading strategies

(Langer, 2001). Part of the problem is that as students move into domain-specific classrooms in high school, content teachers are often underprepared to meaningfully support reading comprehension generally and domain-specific reading in particular (Gomez, Herman, & Gomez, 2007). Several teachers have reported to us that it should primarily be the responsibility of middle school English teachers to get students "ready to learn science." High school science teachers are under pressure to cover science content standards. Still, science teachers are frequently frustrated by students' inability to learn from texts, even if they are not sure how to address the problem. We have found that science teachers will often assign reading to students, but then didactically teach the "important content" (Gomez, Herman, & Gomez, 2007). This approach fails to hold students accountable for independently accessing and learning from text. This marginalizing of text in science is extremely unfortunate given how central reading to learn science is to any meaningful definition of scientific literacy (Norris & Phillips, 2003). One's ability to comprehend science content from reading is important to the work of scientists in the field, as well as critical to promoting scientifically literate citizens. Although there have been influential calls to action to better integrate literacy within the content domains (Biancarosa & Snow, 2006), there remains little practical advice for content-area teachers that is theoretically and empirically grounded in the disciplines. An important goal of our work is to demonstrate that when students have the chance to learn, practice, and apply reading comprehension strategies that are deeply coupled to domain learning goals and domain practice, content learning will increase along with students' ability to independently read to learn.

Reading Strategies: Structure, Reflection and Gist

Science readers should have a corpus of strategies they can use prior to, during, and after reading to learn from text. Students benefit when they are taught to apply comprehension strategies when they read (Anderson, 1992; Collins, 1991). Through repeated transactions with texts and by collaborative analysis and discussion with peers, students can better internalize and ultimately take ownership of reading strategies (Pressley, et al, 1992; Biancarosa & Snow, 2006). When internalized and used frequently, strategy use can lead to large positive effects on text comprehension (Anderson, 1992). The strategies we support (described in detail below) are designed to help students identify the general structure of texts as well as critical discipline-specific elements such as main and supporting ideas, how scientific arguments are constructed in text, what counts as scientific evidence, etc. (Gomez, Herman, & Gomez, 2007). In addition, the strategies should help students know how to reflect on, analyze, and organize text so that elements can be examined and critiqued for understanding and communication (Herman et al, 2008). Finally, students should also know how to summarize a text to integrate new and prior knowledge into one holistic representation of their understanding. This summarization strategy helps students communicate their understanding of the gist of what they have read, and to make the connections between new and prior knowledge explicit (Kintsch, 1998).

The reading strategies implemented in these science classrooms are intended to increase reading comprehension and science learning by developing students' metacognitive reading skills to increase active and conscious processing of text. Though there are many conceptualizations of metacognition in the literature, we focus on developing students' conscious control of their cognitive processes (i.e., self-regulation) (Pressley, 2000), including planning, selecting, and using appropriate strategies; monitoring reading comprehension; analyzing the effectiveness of reading strategies; and changing reading behaviors when necessary (Ridly, Shutz, Glanz, & Weinstein, 1992). We conjecture that increases in metacognitive reading skills will allow students to comprehend more challenging text. Over time, as teacher support fades and reading strategies are internalized, students will be able to read challenging texts more independently. Ultimately, these conscious reading strategies will develop into reading skills (Afflerbach, Pearson, & Paris, 2008). Next we describe each of the three classes of reading strategies in detail.

Annotation

Text annotation is a strategy to make an author's message more explicit to the reader. Students are taught how to identify and mark important information, and disregard irrelevant information. Students typically annotate (by marking on the text) one or more text elements such as difficult vocabulary words and embedded definitions; main ideas/arguments and related supporting ideas/evidence; and headings, transitional words, and other signposts. Initially, teachers explicitly model this annotation process, but over time reduce their scaffolding for annotation so that students can independently annotate texts. Figure 1 is an example of a student's annotation from one of the two texts used in the study described later.
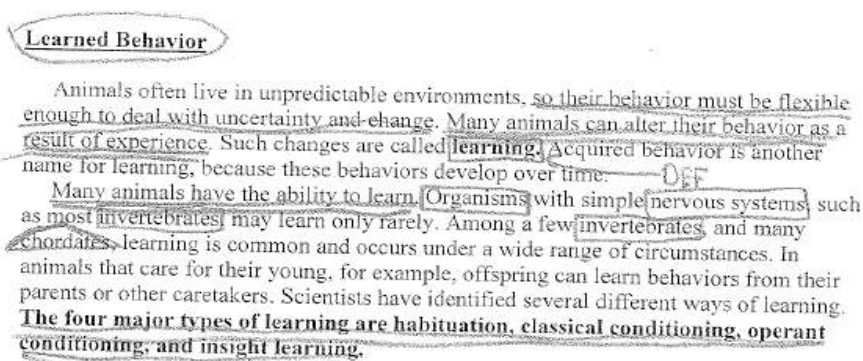
Figure 1. Example of a Student's Annotation.

Double-Entry Journals

A double-entry journal (DEJ) (See Figure 2) is a reader-response log that provides a structure for students to monitor and document their understanding of science texts. The DEJ provides students with an organizational tool that suggests corresponding categories of information that students extract from the text, rearrange, paraphrase, and use to reflect on their understanding. The variety of DEJ structures allows teachers to focus students' reading on an important idea or skill that is particularly relevant for a given text (vocabulary, main ideas with supporting ideas, relating information in the text to prior knowledge, etc.), thus coupling the DEJ (and students' attention) to the targeted content learning goal.

Figure 2. Example of a Double-Entry Journal.

Summarization

Summary writing is a critical scientific skill. It requires the reader to effectively digest new information and communicate it in a way that makes sense to her as well as to an external audience. Summarization is a particularly difficult task when students are trying to make sense of texts that exceed their nominal reading level, as is the case for many high school students. In summarizing, students must comprehend the text, identify main ideas, differentiate secondary ideas, integrate new knowledge with prior knowledge, and condense the information in a succinct and logical way.

Reading Strategies, Science Learning, and Scientific Literacy

Being a competent science learner requires students to learn about science from texts in many forms, including readings, graphs, charts, and other representations of phenomena, processes, and data. Reading to learn science, though certainly not the only competency that accounts for success in school science learning, is nonetheless a constitutive element of students' success in high school classrooms and beyond. In fact, almost any definition of scientific literacy includes the ability to read texts to understand scientific phenomena and thought (Norris & Phillips, 2003). Teachers and students make the strategies science-specific by the tasks they engage in with the strategies. For example, though a double-entry journal could be used in a History class to analyze the causes of a particular war, it is used in science to help students better understand how good scientific arguments require explicit forms of evidence. In this sense, though the *forms* of the strategies are generic, our work has been to deeply couple them *in function* to science learning objectives and scientific literacy.

The Present Study

Few studies to date have focused on evaluating an ongoing program whose goal is to boost science achievement by focusing on science-specific applications of reading comprehension strategies in intact science classrooms. Most studies of reading strategies have been episodic and somewhat uncoupled from classroom learning goals. Furthermore, few studies have taken place at the high school level (Cromley & Azevedo, 2007), and almost no

studies have linked strategy use to domain learning. Strategy interventions have not typically been designed to be discipline specific but rather generic, in the sense of being applicable across disciplines. In this work, we also want to provide an empirical (not just theoretical) base for the design of strategy supports for learners. We want evidence that the annotation, DEJ, and summary activities that we prescribe are effective in increasing science learning. To do so requires revision of the design of strategies, which were initially based on theoretical models of what students should attend to in readings. An important goal of this work is to better understand the connection (both theoretically and empirically) between reading comprehension and domain achievement. Our approach is to support science teachers as they contextualize the reading comprehension strategies in the discipline of biology.

Research Questions

1. Is proficiency with the reading strategies related to science achievement?
2. Does proficiency with the reading strategies predict achievement above and beyond on-entry reading ability?
3. Can the empirical results in this study inform the refinement of science-specific reading strategy design?

Participants

All of the work reported here took place during the 2008-2009 school year at a large suburban high school abutting Chicago, IL. Approximately 2,950 students attend the school with 48% being Caucasian, 36% Black, 11% Hispanic. Thirty-four percent of the students are classified as low-income based on eligibility for free or reduced lunch. Approximately 70% of graduates in recent years attended college. In 2005, the school adopted the broad goal of integrating literacy across the content areas. Starting in 2007 administrators and instructional leaders (including a co-author who is chair of the science department) met with our research team to develop a literacy initiative specifically for the science department. Based on what we learned from our prior work focused on embedding literacy in science classrooms (Herman et al, 2008), we worked with a pilot group of biology teachers to introduce ways to couple literacy activities to science learning goals. During the 2008-2009 school year, the intervention expanded to every biology classroom. All biology teachers were provided with ongoing professional development and coaching (by a co-author who had been a high school science teacher at an earlier research site). Fifteen science teachers and approximately 860 students participated in the study.

Design of the Assessment

Teachers and students in all participating classrooms used the three reading strategies throughout the fall of the 2008-2009 school year (Annotation, Double-Entry Journaling, and Summarization). In January and June of 2009, we administered a one-day assessment of strategy proficiency and science achievement. 752 students were present on both dates and completed both sets of assessments. The design of this assessment was informed by our prior work (Herman et al, 2008), in which we used a point-in-time assessment to gauge how well students were independently able to use the literacy strategies while reading science texts, and the resultant effect on science achievement. It is worth stressing that the assessments described here measure both students' *independent* understanding of, and proficiency with, the reading strategies as well as their *independent* understanding of the science content in the readings. The format of the January and June assessments was identical: Students were randomly assigned one of two readings ("Learned Behavior" or "Coral Reefs") and randomly assigned (within classrooms) to use one of the three strategies while reading the text. Finally, students completed a 10 item multiple choice science assessment that was based on the content in each of the readings. Students used the same class of strategy during both assessment days but the reading and science assessments were crossed so that if a student completed an annotation of the Behavior article in January, they would be assigned to complete an annotation of the Coral article in June. Though we designed and administered two assessments four months apart in order to understand something about growth trajectories in strategy acquisition, that is not the focus of this paper and space limits prevent us from presenting the longitudinal analysis. Instead, the assessment results are grouped together for the analyses presented here.

Coral Reefs and Learned Behavior

The two readings were chosen from the students' biology textbook. They represent two genres of science texts that students are exposed to: The Learned Behavior text is a more traditional expository reading, whereas Coral Reef is a magazine-type article, representative of the type of chapter inserts that are included in the textbook. In addition to genre differences, the texts were chosen because neither of those topics would be covered in the science classrooms for the duration of the study, thus reducing the likelihood of prior knowledge effects on the science achievement assessment.

Science Achievement Assessment

For each reading, 10 multiple-choice items were developed. To develop the candidate items, we first analyzed some of the science learning objectives for students that were encapsulated in the content of the texts. We then used those science learning objectives to generate individual items that would assess students understanding of the science content. The construction of this assessment was disciplined by two constraints: 1) As much as possible, we did not want prior knowledge to allow students to answer any of the items so as to better couple success on the items to successful reading of the passage, and 2) We wanted classes of items that varied in difficulty and we wanted that difficulty to be approximately the same across passage assessments. To ensure that the effects of prior knowledge were minimized, we designed a measure that listed the major concepts from each reading and asked students to rate their familiarity and understanding using a Likert-type scale. We gave the prior knowledge measure to 54 students, and piloted the candidate items on 98 students who would not be in the classrooms of the study, but who had covered the same biology content the prior year. These students did not have access to the Behavior or Coral readings; they only completed the multiple-choice items. Based on those results, we altered the item stems, the distracters, and the answer choices. Examples of the items that made up the assessment at three levels of difficulty (Recall, Application, Synthesis) are presented below.

1. (Recall)   Which of the following is not associated with operant conditioning?
2. (Application) How does a slow growth rate impact the survival of the coral reef?
3. (Synthesis)   Coral polyps would be prevented from obtaining food in the presence of:

Scoring

To measure strategy proficiency, two of the authors developed a rubric for each reading and for each strategy. Thus, for the Coral article there was a separate rubric for Coral annotation, Coral DEJ, and Coral summary. The rubrics were designed to measure those elements of, say, an annotation, that were deemed by the researchers to be important for correctly answering one or more of the 10 science achievement questions. Figure 3 is a list of examples of the elements that were used in the different rubrics.

Annotation – Did the student…?
- Box the vocabulary word *mutualism?*
- Double underline the main idea: "Coral reefs make up a natural ocean habitat that is rich in diversity."

DEJ – Did the student include…?
- Main idea #1: "The four major types of learning are habituation, classical conditioning, operant conditioning and insight learning."
- Supporting idea #2: "Many animals can alter their behavior as a result of experience. Such changes are called learning."

Summary – Did the student…?
- Make a connection between runoff from clear-cutting forests and the blocking of light for the habitat?
- Use the vocabulary word *mutualism?*

Figure 3: Example Elements From Scoring Rubrics

Two of the coauthors scored all student strategy work. To ensure the reliability of scores, the two investigators scored 20 identical student work samples to determine the inter-rater reliability of rubric-based scores. When scores were disparate (less than 85% agreement), the scorers talked through their understanding of the rubric and student work. The rubrics were then modified to reflect this shared understanding. The scorers then processed another independent sample of strategy examples, and inter-rater reliability increased to acceptable levels. This reliability check was done for each of the six rubrics.

Results

Descriptive statistics for all measures are in Table 2. The reading percentile is the national percentile rank on a standardized test of reading for each student. This percentile is used as a covariate and represents on-entry reading achievement. The students vary widely in reading ability but the mean of 66.91 indicates on average they are above the 50th percentile nationally on reading. The strategy proficiency scores indicate a wide range of proficiency. For each element, a student may receive a 0 or 1 (except for a few items on the annotations that allowed for a 0, 1, or 2). The strategy proficiency scores represent the total score across all the elements in a particular rubric (i.e., the Behavior annotation). It is worth noting that in some cases not one student was able to receive all possible points on the strategy rubrics. The Coral science achievement assessment was slightly more difficult than the Behavior assessment, even though we made every effort to make the two assessments equally difficult.

Correlations were calculated so that we could determine, for all students who completed a Behavior annotation

in either January or June, whether their strategy score was correlated with science achievement. Every strategy for both readings was correlated with performance on the science assessment. The correlations were significant ($p<.01$ in all cases). Correlations for Behavior ranged from .23 for Annotation to .42 for both DEJ and Summary. For Coral the range was from .35 for both Annotation and DEJ to .33 for Summary. The correlations are more consistent (within each reading) for DEJ and Summary than they are for Annotation. The Behavior annotation correlation was the smallest (.23) though it was still significant.

Stepwise Regressions were performed to determine whether strategy proficiency predicts science achievement even after entering prior reading on a standardized exam as a covariate in Step 1. The results of these regressions are highlighted in Table 3. In each model, strategy proficiency predicted unique variance in science achievement above and beyond what reading alone predicts. Because reading is presumed to be a consistent predictor of performance on most academic outcomes, including science, these results may indicate the value of the reading strategies as a means of raising both science achievement and reading comprehension. In some cases, the amount of variance explained by strategy proficiency above and beyond reading was not large (2% of the variance for Behavior Annotation; while in other cases the effect was larger, as in the case of Behavior Summary (7% of the variance). Because we included a "strong" covariate, these numbers are somewhat encouraging in that they suggest that proficiency with the strategies might be helping students learn more science, even if they are struggling with reading.

t-tests and ANOVA: We conducted an analysis of each element of each rubric independently of each other to determine if particular items on the rubric "mattered more" in predicting science achievement. In prior work (Herman et al, 2008) we found an inconsistent relationship between annotation score and achievement. In this study, annotation score did predict achievement. In follow-up analyses to our main study, we essentially conducted a simple differential item analysis. For example, on Behavior Annotation item #3, students would receive either a 1 or 0 depending on whether they identified a main idea in the Behavior reading by underlining it. We analyzed the total science comprehension score to determine if there were differences in that score based on whether students received a 0 or 1 on item 3. We grouped all students into two groups for each item and then compared the science score for each group. We used t-tests when the items were scored 0 or 1 and a One-Way ANOVA when scored 0,1, or 2. Though we realized that by using more than 20 comparisons, we were likely to allow for increased likelihood of Type I errors, we were primarily interested in exploring patterns in the predictive utility of elements of the rubrics. So, for Behavior Annotation, there were 30 items on the original rubric and our empirical analysis indicated that only 8 of those items differentiated students reliably on their total science scores. Once we identified those 8 elements, we recalculated the correlation of strategy proficiency with achievement based on those 8 items instead of the original 30. Though we would expect the correlation to increase because our method necessarily would lead to less variance in the predictors, we wanted to gauge how strong those correlations would be for possible future revisions of the annotation format. In this case, the correlation rose from .19 to .36. In all cases, for both readings and all 6 strategies, the correlations rose with the lowest being .32 and the highest being .43. For each strategy we now have an empirically based subset of items that better discriminates the total science score (not each question on the science test but the mean on the 10 items for each student). The number of revised elements for each strategy compared with the total number of elements for each, is as follows: Behavior Annotation 8/30, DEJ 12/16, Summary 7/12, Coral Annotation 17/27, DEJ 8/18, and Summary 8/18. In each case, a substantially fewer number of items does a better job of predicting the science score.

Table 1: Descriptive Statistics of Variables in the Study

	N	Possible Range	Actual Range	Mean	Std. Deviation
Behavior Annotation	210	0-37	2-37	20.66	6.07
Behavior DEJ	212	0-16	0-14	5.06	2.74
Behavior Summary	187	0-12	0-9	3.91	2.30
Coral Annotation	209	0-36	1-34	15.70	7.28
Coral DEJ	209	0-18	0-14	6.74	3.03
Coral Summary	189	0-18	1-15	6.26	2.98
Behavior Assessment	856	0-10	0-10	6.34	2.05
Coral Assessment	844	0-10	0-10	6.06	2.08
Reading Percentile	856	1-100	1-100	66.91	28.01

Table 2: Regressions for 6 models: Predicting science achievement from strategy proficiency and reading.

Behavior	Models*	F	Adjusted R^2 (Reading only)	Adjusted R^2 (Reading + Strategy)
Model 1*	Reading Achievement + Annotation	41.07	.27	.29
Model 2*	Reading Achievement + Double-Entry Journal	63.71	.37	.40
Model 3*	Reading Achievement + Summary	42.33	.25	.32
Coral				
Model 4*	Reading Achievement + Annotation	36	.23	.26
Model 5*	Reading Achievement + Double Entry Journal	46.65	.31	.33
Model 6*	Reading Achievement + Summary	59.37	.37	.39

*$p<.02$ for each predictor in each model

Discussion

Several findings from this study are worth highlighting. Students who successfully used reading comprehension strategies while reading a science text performed better on a measure of science achievement. That is an important finding for the adolescent literacy and science education research community as well as for practitioners who might wonder about whether the support of reading in high school science classrooms is possible, practical, and useful. This study indicates it is useful to regularly incorporate explicit instruction in reading comprehension strategies in science classrooms, not as a way to primarily improve students' reading abilities, but as a means of increasing science achievement. Science teachers (and other content-area teachers) need better ways to support reading in the disciplines. All too often in science class, readings are ignored or marginalized. Teachers are not to blame for this. Most schools of education provide high school science teachers with almost no preparation for supporting reading in science. Teachers need to know and be able to scaffold a variety of effective reading comprehension strategies that can help increase science learning. This kind of work requires extensive, practice-based, and ongoing professional development.

This study also shows that reading plays an important role in science achievement. The regression models indicate that reading achievement is a significant predictor of science achievement. This finding, though not unexpected, is important because it adds to the understanding of how reading achievement matters for various formats of science assessment, for a variety of learning goals and science text genres. A demonstration of how much reading matters can be a powerful way to spur science teachers to acknowledge and ultimately take some ownership of students' reading abilities in science. We have seen in prior work (Authors, 2007) that science teachers do take ownership over reading when they have a repertoire of teaching strategies that they can utilize and when, as in this case, they can see the significant connection between reading and science achievement. The measure in this study is very similar to other classroom measures of science achievement. We acknowledge that the measure used is not a "pure" measure of science achievement; it is also a measure of reading comprehension. However, we suggest that many classroom assessments of science learning are reading-dependent in meaningful ways.

Student proficiency with any of the strategies was related to student performance on the science assessment. This is worth noting, particularly because that relationship holds even when on-entry reading ability is a covariate in the regression models. Strategy proficiency predicts unique variance in science achievement even when controlling for reading. Based on the adjusted R^2s, reading achievement and strategy proficiency account for between 26% and 40% of science achievement. In prior work (Authors, 2008), we found that proficiency with annotation, though correlated with science achievement, did not predict science achievement when accounting for on-entry reading. We suspect that the reason annotation inconsistently predicts achievement might have to do with the variety of ways that students have learned to annotate. It is possible that only certain elements of annotations matter to comprehension because students may not be actively engaged in completing all the elements of an annotation with all readings. To better understand whether this is true, we conducted some further analyses of our data and identified the subset of elements of the annotation that most differentiated student science achievement. For example, as we mentioned earlier, for the behavior annotation, 8 of the 30 elements significantly differentiated students who did better or worse on the science achievement. The prior research indicated that annotation strategies have utility if they help students recognize and leverage the

structures of text for understanding. But, the results of the preliminary analysis presented here indicate that perhaps only the content-focused steps in annotation (like marking main ideas or differentiating specific evidence that supports a particular argument) is important in increasing science learning, and that the more conceptual-focused steps (like circling a heading or subheading) are less useful. There is some evidence that the revised elements are more content focused than conceptually focused. The empirical evidence about strategy efficiency is very important because any intervention that stresses reading comprehension will have to be implemented in real classrooms by busy science teachers. It will require ongoing effort to support schools so they routinely use comprehension-focused, discipline-specific reading strategies in science. Teachers need to be sure they help students learn science. We have provided initial evidence that they do.

Perhaps the major challenge to improve reading in the domains in high school is not discovering new strategies that work but rather researching ways to impact school practice through the kind of research described here. Learning science research can be an important resource in the transformation of science instruction. Much is known about how to teach early elementary reading, and many schools have now put into practice what was only a research agenda a decade or two ago. We do not know nearly as much about high school reading, but we have some good ideas to put into place. Learning scientists need to collaborate closely with schools to make more routine what we know to be effective. Explicit attention to comprehension-focused reading strategies is probably one piece of a good solution to the challenge of supporting reading to learn competencies. This study makes some progress in providing evidence about the utility of strategies, but also goes beyond that by examining how the instructional versions of strategies might be altered by empirical evidence. This could be the most important, if preliminary, contribution of this work. The reading strategies movement was based in large part on a theoretical model of how strategies could help readers. In the case of annotation, it was based on a largely theoretical assertion that readers could better leverage the structures of texts in order to better comprehend text. Good readers seem to better leverage the structure of texts. So, we (and others) designed annotation supports based on that insight. But now we are able, in part by the empirical analysis presented here, to begin to revise and better understand how to link reading activity support to specific science learning. This is an important future direction of this work.

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