International Electronic Journal of Elementary Education, 2011, 4(1), 19-31.

Improving middle and high school students' comprehension of science texts

Brandi E. JOHNSON
Georgia State University, United States

Karen M. ZABRUCKY *
Georgia State University, United States

Abstract

Throughout the United States, many middle and high school students struggle to comprehend science texts for a variety of reasons. Science texts are frequently boring, focused on isolated facts, present too many new concepts at once, and lack the clarity and organization known to improve comprehension. Compounding the problem is that many adolescent readers do not possess effective comprehension strategies, particularly for difficult expository science texts. Some researchers have suggested changing the characteristics of science texts to better assist adolescent readers with understanding, while others have focused on changing the strategies of adolescent readers. In the current paper, we review the literature on selected strategy instruction programs used to improve science text comprehension in middle and high school students and suggest avenues for future research.

Keywords: reading comprehension, comprehension of science texts

Introduction

Reading comprehension involves a set of multifaceted and interconnected skills allowing students to accurately process and understand text information during reading (Zimmerman, Gerson, Monroe, & Kearney, 2007). The processes involved in reading comprehension include, in part, focusing on relevant and important information from a passage and making connections between that information and prior knowledge. But students must also understand the meaning of words as well as integrate the many internal connections among important and relevant pieces of information within a passage (Baker, 1985; Cook & Mayer, 1988). Several researchers (e.g., Cook & Mayer, Magliano, Todaro, Millis, & Wiemer-Hastings, 2005) have expanded upon the typical definition of comprehension by

* Karen M. Zabrucky, Department of Educational Psychology and Special Education, P.O. Box 3979, Georgia State University, Atlanta, GA , 30302-3979, United States. E-mail: zabrucky@gsu.edu

ISSN:1307-9298

www.iejee.com

suggesting that deeper comprehension results from students purposefully trying to reach a coherent understanding of what a text is about. When reading difficult texts, skilled readers use a variety of comprehension strategies to build deeper meaning.

Within the United States, large proportions of middle and high school students struggle to read and understand content area textbooks. It is not uncommon, within some schools, for 75-80% of the students in a significant number of classes to be unable to successfully read textbooks (Carnine & Carnine, 2004). The epidemic has become so great that the state of California designated a new category for such students, labeled "struggling readers." According to Bhattacharya (2006), students must accurately and fluently read passages containing extensive vocabulary with multiple syllables to successfully comprehend content-area texts. Students tend to struggle in particular with comprehension of science texts. Even if they can decode, read, and understand the words in the texts, students have problems making the words make sense. The words appear as a string of known and unknown words rather than a message that is coherent, comprehensible, and learnable for students (Best, Rowe, Ozuru, & McNamara, 2005).

Factors Contributing to Students' Difficulties Comprehending Science Texts

Science Texts: Content and Structure Issues

Several factors may contribute to students' poor lack of understanding of science texts. The texts themselves may cause problems because science texts are frequently inaccurate, focused on isolated facts, boring, and poorly organized (Chambliss & Calfee, 1989). Carnine and Carnine (2004) further criticized science texts by stating that such texts contain too many vocabulary concepts, present too many ideas at once, lack clarity, and fail to transmit science knowledge. Several of these characteristics would appear to fly in the face of fundamental processes that affect ease of text comprehension (Kintsch & van Dijk, 1978).

It is very likely that students' comprehension skills contribute greatly to their struggles with science texts, which may be too demanding for students' skill levels. According to Cook and Mayer (1988), students may be unaware of the underlying structure of passages within a science text. The construction integration (CI) model of text comprehension emphasizes that domain-knowledge drives text comprehension and, thus, students with limited existing knowledge of science concepts will experience difficulty comprehending science texts (Best et al., 2005).

There are several approaches taken by researchers to improve students' comprehension of science tests. One approach involves changing the design of science textbooks. Chambliss and Calfee (1989) found multiple differences in science textbooks for nine-year-old students in Japan, Singapore, and the United States. In comparison with texts from the other countries, science texts from the United States were not only larger but more cluttered with information and details, resembling incoherent compilations rather than "teaching books" (p. 313). Moreover, science texts use an expository rather than narrative structure more familiar to students (Cook & Mayer, 1988).

The expository texts used in school classrooms are often low in cohesiveness and too demanding for students with little background knowledge in a particular content area. Experts who write such expository texts often inaccurately assume that students possess prior knowledge of subject matter similar to the writer's prior knowledge. As noted by Best, Floyd, and McNamara (2008) "In contrast to narrative texts, expository texts tend to place increased processing demands on the reader due to their greater structural complexity, greater informational density, and greater knowledge demands " (p. 140).

Studies show that texts with high cohesion benefit readers with less domain knowledge (Best et al., 2005). Chambliss and Calfee (1989) recommend that in large science texts, content should be organized coherently and explicitly. Authors should intertwine subject matter with student knowledge and use functional devices like introductions, transitions, and conclusions to pull text information together. Carnine and Carnine (2004) also argued that extraneous information in middle school textbooks was greatly reduced when the content was simplified and instruction focused on a few key concepts. To improve retention of text information the authors encouraged review of core concepts through the use of embedded questions throughout a text and use of discussion questions to direct class discussions related to a text.

Students' use and knowledge of relevant strategies for comprehending science texts

While some researchers interested in improving students' comprehension of science texts have focused on the issue of making textbooks more coherent, others have conducted systematic examinations of students' strategy use. In the present article, we will review research on selected programs used to improve middle and high school students' comprehension of science texts.

According to the 2000 National Assessment of Educational Progress (NAEP) in science, only 32% of the nation's 8th graders performed at or above the level of *Proficient.* Further, the number of 12th graders performing at or above the *Basic level* declined between 1996 and 2000 (Carnine & Carnine, 2004). Eighth grade students who perform at the *Proficient* level demonstrate much of the knowledge and many of the reasoning abilities essential for understanding of the Earth, physical, and life sciences at a level appropriate to grade 8, while seniors performing at the *Basic* level demonstrate some knowledge and certain reasoning abilities required for understanding of the Earth, physical, and life sciences at a level appropriate to grade 12 (National Center for Education Statistics: A Nation's Report Card Science, 2010, para. 16). Meanwhile, the 2003 NAEP in reading revealed that 26% of eighth graders could not read at the basic level, indicating that many adolescents do not understand what they read (McNamara, O'Reilly, Best, & Ozuru, 2006). Eighth-grade students performing at the *Basic* level should demonstrate a literal understanding of what they read and be able to make some interpretations. When reading texts appropriate to eighth grade, they should be able to identify specific aspects of the text that reflect overall meaning, extend the ideas in the text by making simple inferences, recognize and relate interpretations and connections among ideas in the text to personal experience, and draw conclusions based on the text (National Center for Educational Statistics: A Nation's Report Card Reading, 2010, para. 16).

The statistics regarding student performance on the science and reading NAEP show why there is a growing concern in the United States with students' ability to read, comprehend, and learn from texts, especially in the area of science. Too many middle and high school students struggle with reading and comprehending science texts. Increasing the percentage of students who can successfully comprehend science textbooks requires an improvement in students' comprehension strategies.

iSTART. One program examined by researchers to help middle and high school students learn strategies and improve comprehension of science texts involves an animated conversational agent called Interactive Strategy Trainer for Active Reading and Thinking (iSTART). Graesser, Jeon, & Dufty (2008) suggest that animated conversational agents, which actually interact with students, help students learn by holding a conversation with the students and/or modeling good pedagogy for them. Students communicate with the agents by talking to them, using a keyboard, making gestures, or using a touch panel screen or input channels. The agents communicate back with students through speech, facial expressions, gestures, posture, etc (Graesser et al., 2008).

iSTART is a web-based reading strategy program that helps students learn metacomprehension strategies that support them in developing a deeper comprehension as they read difficult science texts (Graesser, McNamara, & VanLehn, 2005). iSTART stemmed from a successful classroom intervention called Self-Explanation Reading Training (SERT) that combined self-explanation, or explaining what a sentence or portion of text means, with reading strategy training. Training resulted from empirical findings that revealed that students who can self-explain are more successful at solving problems, more likely to generate inferences, construct more coherent mental models, and develop a deeper understanding of the concepts discussed in a text (McNamara et al., 2006). Graesser et al. (2008) noted that iSTART requires students to create self-explanations of text by using the five reading strategies of monitoring comprehension, paraphrasing explicit text, making bridging inferences between the current sentence and prior text, making predictions about the subsequent text, and elaborating the text with links to what the reader already knows.

iSTART consists of three modules which include an introduction, demonstration, and practice. During the introduction, students receive information about five reading strategies from two animated students and a teacher animated conversational agent. After learning about a strategy, the students complete a multiple-choice quiz to assess their understanding of the strategy (Graesser et al., 2005). The second module, the demonstration module, identifies ways that the reading strategies can be used to self-explain expository texts. Specifically, two animated characters, Merlin (the teacher) and Genie (the student), demonstrate the use of self-explanation. The students receiving training identify and select on a computer screen the strategy Genie used to self-explain a science text. Merlin then provides verbal feedback to Genie about the quality of his self-explanation. Finally in the practice module, the students receiving training type their own self-explanations for science texts and Merlin assesses the quality of their self-explanations and provides feedback to the students (McNamara et al., 2006). Merlin may ask the students to modify self-explanations until the self-explanations reach a satisfactory level. The students must then identify the reading strategies they used in their self-explanations (Graesser et al., 2005).

McNamera et al. (2006) conducted a study to examine the effectiveness of iSTART in helping adolescent readers learn reading strategies, and improve their comprehension of science texts. Participants in the study included 39 children enrolled in a summer learning program in the Eastern United States with approximately half of the students entering the eighth grade and half of the students entering the ninth grade. All participants were administered the Metacognitive Strategy Index (MSI) at their school as a group, one week prior to training. The MSI is a 25-item multiple-choice questionnaire that measures knowledge of metacognitive reading strategies (McNamera et al., 2006). During the training session, the control group, consisting of approximately one half of the students, was provided with only the initial portion of the iSTART introduction, which describes the concept of self-explanation and provides an example of a self-explanation. The experimental group received a one-hour training session for two consecutive days on all three iSTART modules. One day after training, both groups read and explained a text about heart disease. Students were required to self-explain each sentence of the text as they read it, without receiving feedback. Students then answered comprehension questions on paper about the heart disease text. Results revealed that both iSTART training and prior knowledge of reading strategies improved the quality of self-explanation and, therefore, comprehension. Students with more prior knowledge of reading strategies benefited most on bridging inference questions after iSTART training. They were able to make more bridging inferences and elaborations than students in the control condition, which allowed them to perform better on bridging inference questions. Students with limited prior knowledge of reading strategies before iSTART training learned how to develop a coherent understanding of the information presented in the text and therefore performed better than controls on text-based questions after receiving training (McNamera et al., 2006).

The results of the study by McNamera et al. (2006) were consistent with the results of a similar study in which investigators examined the effect of iSTART on students' comprehension of science texts (O'Reilly, Sinclair, & McNamara, 2004). The researchers administered three aptitude tests, the prior science knowledge test, the Gates-MacGinitie Reading Skill Test, and the MSI to thirty-eight middle school students participating in a Learning Bridge summer program. The investigators wanted to examine students' knowledge of different science domains, metacognitive reading strategies, and level of standardized reading comprehension. One week later, half of the students received two consecutive days of one-hour sessions of training over the iSTART introduction, demonstration, and practice modules. Students self-explained one text about thunderstorms and one text about coal during the practice module by typing their explanations into a computer. Remaining students served as a control group and received a description and examples of self-explanation, but did not receive iSTART training or practice with the system. Similar to the study by McNamera et al., (2006) students in the iSTART and control groups then read and self-explained each sentence of a text on heart disease. Students did not receive feedback from iSTART, but did answer comprehension questions about the heart disease text on paper (O'Reilly et al., 2004). Results indicated that iSTART training improved comprehension of science texts, but had different effects on students with high knowledge of reading strategies versus students with low knowledge of reading strategies. Students with high knowledge of reading strategies performed better on bridging questions after iSTART training as compared to the control group. Students with low knowledge of reading strategies performed better on text-based questions than the control group (O'Reilly et al., 2004).

Magliano et al. (2005) supported findings of O'Reilly et al. (2004) and McNamera et al. (2006) by examining changes in reading strategies that occur in readers of different skill levels as a function of iSTART training. The Magliano et al. study took place across four sessions within approximately one month. Each session lasted about an hour and a half. Magliano et al. administered the Nelson-Denny test, a domain specific test, and a general science knowledge test to fifty-three college students enrolled in an introductory psychology course. One week later, the students participated in a pre-iSTART session using Microsoft Excel, in which they were told to type self-explanations of each sentence embedded in two- to five-sentence scientific texts as they appeared on the computer screen. Students were told to self-explain by producing whatever thoughts immediately came to mind regarding their understanding of a sentence in the context of a text. Students then took a short-answer comprehension test after reading both texts.

During the next week, students engaged in the iSTART computerized system at their own pace. The post-iSTART session occurred one to two weeks after the third session. The post-iSTART session was similar to the pre-iSTART session except that during the post-iSTART session, students were explicitly instructed to practice iSTART reading strategies when producing self-explanations. The researchers provided the participants with a list of the strategies and the definitions of the strategies as a reminder (Magliano et al., 2005). The results of the study indicated that only skilled readers engaged in more global processing after iSTART training, but both skilled and less-skilled readers increased their strategy use and produced more relevant self-explanations after iSTART than before. Consistent with prior research, after iSTART training less skilled readers improved their performance on text-based questions, but not bridging questions. However, skilled readers improved their performance on bridging questions.

PALS. Peer Assisted Learning Strategies (PALS) is an alternative program explored by researchers to improve adolescents' reading comprehension of science texts. PALS is a reading comprehension strategy program based on a class wide peer tutoring (CWPT) model. CWPT is a system in which all class members are organized in tutor-tutee pairs and work together rather than independently or in small groups (Calhoun, 2005). It provides students with an increase in practice opportunities, immediate error correction, pacing, content coverage, high mastery levels, and immediate feedback Researchers have found that students participating in CWPT outperform students in control classrooms in reading, spelling and mathematics, at both the elementary and secondary levels (McMaster, Fuchs, & Fuchs, 2006) and that students remain engaged in PALS nearly 100% of the time (Calhoun, 2005).

Given that inquiry plays a significant role in the scientific process and requires students to be engaged, teachers must find ways to encourage student engagement in science classes (Kroeger, Burton, & Preston, 2009). Peer-mediated instructional practices like CWPT and PALS may support science learning by keeping students engaged and PALS has been shown to improve students' comprehension of science texts while keeping them engaged (Kroeger et al., 2009). Approximately fifteen years of pilot studies, component analyses, and large-scale experiments conducted within classrooms have indicated that PALS improves the reading achievement of low, medium, and high achieving students (McMaster et al., 2006). In fact, PALS earned *Best Practice* status from the U.S. Department of Education Program Effectiveness Panel (McMaster et al., 2006).

According to Calhoun (2005) students participate in three essential reading comprehension activities while reading aloud during PALS. The activities include Partner Reading with Retell, Paragraph Shrinking, and Prediction Relay. All three activities are designed to provide students with practice in reviewing, sequencing, stating main ideas, summarizing main ideas, and predicting outcomes. For each activity, the higher-performing student reads the text first, followed by a lower-performing student who acts as the first Coach. The readings come from texts that are at an appropriate level for the lower-performing student in each pair (McMaster et al., 2006).

During Partner Reading with Retell each student reads aloud from connected text for five minutes. The higher-performing reader reads a passage in a text. If the reader makes an error while reading, the Coach asks the reader to stop reading and sees if the reader can figure out the word. If so, the reader says the word and continues reading. If not, the Coach tells the reader the word. The reader then repeats the word and rereads the sentence. The students then switch roles. After both students read, the lower-performing student retells the sequence of events read for two minutes. Students earn a point for each sentence read correctly and ten points for the retell (McMaster et al., 2006).

Paragraph Shrinking constitutes the second PALS activity. During Paragraph Shrinking, the students continue to read aloud, but they stop at the end of each paragraph to identify the main idea. The Coach asks the reader to identify who or what the paragraph is talking about and the most important thing about the "who" or "what." The reader then condenses the information into ten words or less (McMaster et al., 2006). The reader earns one point for identifying who or what the paragraph is talking about, one point for stating the most important thing, and one point for stating the main idea in ten words or less (McMaster et al., 2006). After one reader shrinks a paragraph, then the roles of Coach and reader reverse for students.

The final PALS activity is Prediction Relay. Prediction Relay consists of the reader making a prediction about what will happen on the next half page to be read, reading the half page aloud, confirming or disconfirming the prediction, and summarizing the main idea (McMaster et al., 2006). The tutor can disagree with a prediction and ask the reader to make another one. During Prediction Relay, students earn points for making reasonable predictions, reading each half page, accurately confirming or disconfirming the prediction, and identifying the main idea in ten words or less (McMaster et al., 2006).

Fuchs, Fuchs, and Kazdan (1999) provided evidence that peer-assisted learning can have a substantially positive effect on struggling high school students' reading comprehension. Their study consisted of 102 students divided into nine control and nine comparison remedial or special education classrooms within 10 high schools in a southeastern school district. Teachers in the control classrooms provided reading instruction two to three times a week over 16 weeks, using conventional reading programs without peer-assisted learning. Teachers in comparison classrooms provided the three PALS activities in their classrooms for the same amount of time.

Although the researchers randomly assigned teachers to control or comparison groups, the teachers identified the students whose data would be included in the analysis. These students all read between grade levels two and six. While the results of pre and post assessments on the Comprehension Reading Assessment Battery were not statistically significant between control and comparison groups, the researchers classified the effect of peer-assisted learning in this study as important because the effect size was greater than 0.25. Furthermore, results indicated that the average student in the control group would have gained at least 13 percentile points in achievement if the student had received PALS training.

Typically, PALS is used to supplement existing reading programs (Calhoun, 2005). Calhoun examined the combined effects of Linguistics Skills Training (LST) and PALS on the reading skill acquisition of middle school students with reading disabilities (RD). LST encompasses an age-appropriate, peer-mediated phonological skill program that uses an explicit linguistic signaling and coding system that enables students to identify the sounds of letters or letter clusters. In this study, four teachers from two middle schools in the southwest participated. Each instructor taught language arts to students with RD in a self-contained classroom. Calhoun's sample consisted of thirty-two sixth graders, five seventh graders, and one eighth grader. All students read at least three grade levels below their expected reading level. Teachers incorporated PALS twice a week with their students and LST three days a week. After 31 weeks of intervention using LST/PALS, students significantly increased their reading comprehension skills compared to a control group that used the widely used remedial reading program Saxon Phonics Intervention. LST/PALS was also effective in teaching students phonological skills even though reading fluency did not improve (Calhoun, 2005).

While most investigators have examined the use of PALS in reading narrative texts, Kroeger et al., 2009, looked at the use of PALS with expository science texts. Researchers used an adapted version of PALS, PALScience, in two classrooms with approximately 28 students in each classroom. The study took place in a large Midwestern suburban middle school. PALScience incorporates the reciprocal peer tutoring and Paragraph Shrinking activities consistent with PALS literature, but not the Prediction Relay activity.

The two teacher-researchers involved in the study chose a single-subject withdrawal design to measure intervention effects, allowing them to focus on the individual changes of students. Initially, all students were trained on the use of helping skills, catching mistakes, making positive comments, and the use of self-monitoring skills to be effective tutor-tutee partners (Kroeger et al., 2009). In the baseline and withdrawal phases of the study, students read science passages with no peer assistance. Passages were selections from seventh-grade classroom science texts that ranged from the fourth through twelfth grade reading levels. The variety of reading levels in the science book chosen is consistent with typical science textbooks (Kroeger et al., 2009). During the intervention phases, students identified as competent in reading, based on a curriculum based assessment, read science passages with students possessing weaker reading skills.

The two teachers also modeled how to construct main ideas. After assembling their own main ideas, students documented them in their science journals during the PALScience Paragraph Shrinking activity (Kroeger et al., 2009). The teachers used a cloze procedure throughout the study to measure comprehension. Results indicated that PALScience improved student skills and overall performance on cloze activities. Although 70% of students responded on a survey that they did not like PALScience for various reasons such as, "You had to read," (Kroeger et al., 2009, p. 13) and "I didn't know my partner," (Kroeger et al., 2009, p. 13) 61% of students commented that PALScience helped them learn important things like, "How to read and comprehend paragraphs," (Kroeger et al., 2009, p. 13) and "To pay more attention to my reading" (Kroeger et al., 2009, p. 13).

PLAN. PLAN represents a study-reading program specifically used in middle school classrooms to improve comprehension of science texts. PLAN stands for Predict, Locate, Add, and Note. Students predict the content and structure of a text and assess its purpose by creating a diagram or probable map of the author's ideas as expressed in the chapter title, subtitles, highlighted words, and graphics (Caverly, Mandeville, & Nicholson, 1995). The map represents students' predictions of the importance of the chapter concepts and the ordered relationships among them. After students predict, they locate known and unknown information on the map by placing checkmarks next to familiar concepts and question marks by unfamiliar concepts. According to Caverly et al., (1995) as students read the chapter, they add words or short phrases to their map to explain the concepts marked with question marks and confirm and extend concepts with checkmarks. Finally, students take note of their new understanding by completing tasks such as summarizing the information, discussing it, and reconstructing a new map.

In one study researchers implemented PLAN in two science classes in a rural middle school. The study included a single-group pre-test/post-test design with one class of fifteen seventh-grade students and another of eighteen eighth grade students (Radcliff, Caverly, Peterson, & Emmons, 2004). Students were taught by a teacher who had completed a graduate course focusing on integrating reading strategies into content area teaching. The researchers modeled PLAN during one session of the graduate course and students in the course practiced the strategy in small groups. The teacher then implemented PLAN in two science classrooms during the fall term. In addition, the teacher met weekly, for a total of 15 hours, with researchers to discuss strategic textbook reading and its implementation into the middle school science classrooms (Radcliff et al., 2004).

Results revealed an increase in the percentage of propositions that reflected paraphrasing of content and higher order thinking on students' PLAN maps as PLAN was implemented in the classrooms. Results also revealed an increase in the reading strategy checklist scores from beginning to the end of the study. Interviews with the teacher and students in the study indicated that the PLAN program increased students' willingness and ability to learn from textbook reading (Radcliff et al., 2004).

In a second study the researchers used a nonequivalent-groups, pretest-posttest design to incorporate PLAN into one sixth grade classroom of 23 students and another sixth grade classroom of 27 students used as a control group. As in the previous research, the teacher in this study had participated in a graduate class focusing on how to implement PLAN in her classroom. The teacher met for a total of 15 hours with researchers to discuss the processes of strategic textbook reading and the challenges of implementing them into a middle school classroom (Radcliff, Caverly, Hand, & Franke, 2008). In this study, the teacher taught PLAN to one of her science classes while another class followed her traditional instruction without PLAN (Radcliff et al., 2008). Results indicated that the average score on the comprehension tests for students in the treatment group was significantly higher than the average score for students in the control group. This result occurred despite the fact that the pretests of groups did not differ significantly. A similar trend took place with the reading checklist scores (Radcliff et al., 2008). According to Radcliff et al. (2008) the reading checklist consisted of 10 yes or no questions regarding what strategies students used for reading a textbook chapter and for monitoring comprehension. Reading checklist scores improved significantly between pre and posttest scores for the treatment group but not for the control group. Pre test scores were similar for both groups but posttest scores were higher for the treatment group.

Inquiry based curriculum with reading**.** Much of the recent scholarship on science education has emphasized the importance of inquiry as well as reading in the development of science literacy (Fang & Wei, 2010). An inquiry- based curriculum recognizes science as a process for producing knowledge depending on careful observations and grounded interpretations. It also focuses on the development of skills in acquiring science knowledge, using high-level reasoning, applying existing understanding of scientific ideas, and communicating scientific information. Recently, science educators have expanded their concept of science literacy to include general reading ability because, without the ability to read, students are limited in the depth and breadth of scientific knowledge they can attain (Fang & Wei, 2010).

Fang and Wei (2010) examined the impact of an inquiry-based science curriculum that infused explicit reading strategy instruction in the science literacy development of middle school students. The study took place in ten regular sixth-grade science classes, with two teachers teaching five classes a piece. In three classes per teacher, explicit instruction of reading strategies was taught for an average of 15-20 minutes per week and students had access to a home reading program that encouraged them to read one quality science trade book per week. Each teacher's remaining two classes were used as control groups, provided with an inquiry based curriculum similar to the experimental groups, but without reading instruction (Fang & Wei, 2010). During the 15-20 minutes of reading strategy instruction, the researchers co-taught with teachers using an explain-model-guide-apply (EMGA) instructional program that maintained a review of the previous week's strategy, an explanation of the target strategy for the week, the teacher's modeling of the use of the strategy, and brief guided and independent practices of applying the strategy. Students then checked out a science trade book published by organizations such as the National Science Teachers Association in cooperation with the Children's Book Council, and were reminded daily to use the target strategy when reading the trade book as well as their science textbook (Fang & Wei, 2010). The students also participated in a review session at the end of the fall semester, in which they selected a strategy that was previously taught and used it with a text excerpt from a science trade book. They also participated in a second review session at the end of the spring semester when they got to comment on their favorite strategies.

Results revealed that not only did students in the inquiry-based science with reading curriculum demonstrate more knowledge about science content on the curriculum-referenced science posttest scores, but they also scored significantly higher on the Gates-MacGinitie Reading posttest. Thus, students' general knowledge of scientific content as well as their general reading ability improved based on the inquiry-based science plus reading curriculum (Fang & Wei, 2010).

Rogevich and Perin (2008) found a very effective program to improve science comprehension in students with behavioral disorders (BD) and/or attention deficit hyperactive disorder (ADHD). The program, called Thinking before reading, While reading, and After reading (TWA), was used in conjunction with written summarization (TWA-WS) at a residential treatment facility for adolescents adjudicated as juvenile delinquent by local courts (Rogevich & Perin, 2008). The study took place at the school on the campus of the residential treatment facility and 63 boys ranging from ages 13-16 participated. Thirty-two of the participants had been diagnosed with BD while 31 had been diagnosed with BD plus ADHD. The mean reading test score on the Gates-MacGinitie Reading Test indicated that students read on approximately a fifth grade level (Rogevich & Perin, 2008).

The investigators used a matched comparison design with one treatment group consisting of students with BD who received intervention, another treatment group consisting of students with BD plus ADHD who received intervention as well as two control groups. Control groups consisted of students with BD or BD and ADHD who received traditional literacy practice but not the experimental intervention.

The researchers conducted the study in a total of eight sessions, with three assessment sessions and five instructional sessions. In the TWA strategy with science passages, small groups of learners identified the author's purpose in a written text, determined what they already knew about the topic, set a reading goal, focused on their reading speed, linked their background knowledge to information from the text that was new to them, reread parts of the selection, identified the main idea, orally summarized the information in the text, and reflected on what they had learned (Rogevich & Perin, 2008). Students also completed the WS part of the strategy through pretest, posttest, near transfer, far transfer, and maintenance summarization tasks. Results indicated that TWA-WS was effective on all measures, as compared with practice with the same text without TWA-WS (Rogevich & Perin, 2008).

Implications for Research

The literature on iSTART provides very encouraging results about the use of the program to improve reading comprehension of adolescents and college students. iSTART benefits most students who participate in training, but it benefits them in different ways. All three studies we reviewed demonstrated the ability of iSTART to help skilled readers generate more bridging inferences and less skilled readers to gain a basic understanding of text-based information. Thus, iSTART appears to help students based on their zone of proximal development (McNamara et al., 2006). Future research on iSTART might include how the program could be adapted to the specific needs of less skilled and more skilled readers (Magliano et al., 2005). For example, future versions of iSTART could provide less skilled and low strategy knowledge students with more training in lower level strategies, and more positive feedback for strategies such as paraphrasing. On the other hand, future versions of iSTART could push more skilled readers to go beyond the text and use strategies such as elaboration to create coherence (McNamara et al., 2006).

Literature examining the benefits of peer-assisted learning programs suggests another possibility for improving middle and high school students' comprehension of science texts. Research indicates that PALS improves reading comprehension of struggling adolescent readers, especially those within special education classrooms. Implementation of a modified version of PALS, PALScience, resulted in an improvement in readers' comprehension of science texts. One very positive aspect of PALS is that teachers actually conduct the studies in their classrooms and not in a laboratory setting. Also, PALS can be adapted to use in a variety of grade levels. Researchers have implemented K-PALS for kindergarten students, First grade PALS for first grade students, as well as High School PALS. While studies involving PALS show an increase in reading comprehension, the literature also reveals areas of limitation. The small sample sizes of previous studies and the use of PALS primarily in special education classes prevent results from being as generalizable as desired. Finally, very little research about the use of PALS for expository texts is available.

The study-reading program PLAN represents another approach that shows promise in improving secondary students' comprehension of science texts. Research on PLAN indicates that students use more reading strategies when using PLAN and design PLAN maps demonstrating higher ordered thinking and better paraphrasing of material as time progresses. Radcliff et al. (2008) also showed an increase in reading comprehension tests for middle school students after participating in PLAN. However, research on PLAN is limited. Future research should include its use in high school science classrooms since previous studies have been conducted in middle schools.

The results of Fang and Wei's (2010) study contributed to previous research on reading comprehension of science texts because they conducted their study in a middle school general education science classroom instead of a reading classroom or laboratory. The authors also required that students practice the reading strategies they learned in class outside of the classroom with science textbooks and science trade books. Limitations of this study include the small amount of time spent in class per week teaching reading strategies. More class time may elicit greater reading comprehension and science knowledge. Future research with the inquiry-based science plus reading curriculum should consider more time spent each week in class on explicit reading strategies and greater implementation of the curriculum by science teachers trained in the program.

Limitations of the Rogevich and Perin (2008) study include a small sample size consisting of students with specific diagnoses. Future research should include a larger population of students, more than one teacher, and the inclusion of female students with BD and/or ADHD. Investigators should also examine whether TWA-WS would work well with students who do not possess BD and/or ADHD, to see whether the strategy is effective with a general education secondary population.

Conclusion

According to the NAEP, many secondary students lack the ability to master science concepts and research is clear that adolescents struggle to comprehend science textbooks. An inability to use appropriate reading strategies accounts for one reason why many adolescents cannot comprehend science textbooks. Literature suggests that improving the reading strategies of readers will improve their overall comprehension of science text information. Research provides evidence that students who receive reading strategy instruction show improvement in reading comprehension of science texts.

The purpose of this article was to review literature on reading programs that improve secondary students' comprehension of science texts. The reading program iSTART, PALScience, PLAN, TWA-WS, and an inquiry-based science curriculum plus reading were described in the article. Results from studies conducted using each of the programs were discussed and provide a great deal of support for use of the programs in improving adolescents' comprehension of science texts.

• • •

Brandi E. Johnson is a science teacher at Benjamin Elijah Mays High School in Atlanta, Georgia. She has a BA in Psychology from Spelman College and two master's degrees from Georgia State University, in Urban Teacher Leadership and Educational Psychology. She is currently a doctoral student at Clark Atlanta University in the department of Educational Leadership. Her research interests include science reading comprehension, single-gender classrooms and schools, culturally relevant pedagogy, and school culture.

Karen M. Zabrucky is a Professor of Educational Psychology at Georgia State University. Her academic background includes a Bachelor's degree in Psychology and Sociology, a Master's degree and Ph.D. in Experimental Psychology, and a Postdoctoral Fellowship in Applied Cognitive Psychology. Her research interests include text comprehension and memory, metacomprehension, and memory in the real world. She is on the editorial board of IEJEE and is delighted to serve as editor of IEJEE's special issue on reading comprehension.

References

Baker, L. (1985). How do we know when we don't understand? Standards for evaluating comprehension. In D. L. Forrest, G. E., MacKinnnon, & T. G. Waller (Eds.), *Metacognition, cognition, and human performance* (pp 155-205). New York: Academic Press.

Best, R. M., Flyod, R. G., & McNamara, D. (2008). Differential competencies contributing to children's comprehension of narrative and expository texts. *Reading Psychology*, *29*, 137-164.

Best, R., Rowe, M., Ozuru, Y., & McNamara, D. (2005). Deep-level comprehension of science texts: the role of the reader and the text. *Topics in Language Disorders, 25,* 65-83.

Calhoon, M. (2005). Effects of peer-mediated phonological skill and reading comprehension program on reading skill acquisition for middle school students with reading disabilities. *Journal of Learning Disabilities*, *38*, 424-433.

Carnine, L., & Carnine, D. (2004). The interaction of reading skills and science content knowledge when teaching struggling secondary students. *Reading & Writing Quarterly, 20,* 203-218.

Caverly, D., Mandeville, T., & Nicholson, S. (1995). PLAN: A study-reading strategy for informational text. *Journal of Adolescent & Adult Literacy*, *39*, 190-199.

Chambliss, M. & Calfee, R. (1989). Designing science textbooks to enhance student understanding. *Educational Psychologist, 24,* 307-322.

Cook, L. & Mayer, R. (1988). Teaching readers about the structure of scientific text. *Journal of Educational Psychology, 80,* 448-456.

Fang, Z., & Wei, Y. (2010). Improving middle school students' science literacy through reading infusion. *The Journal of Educational Research*, *103*, 262-273.

Graesser, A., McNamara, D., & VanLehn, K. (2005). Scaffolding deep comprehension strategies through point & query, autotutor, and iSTART. *Educational Psychologist, 40*, 225-234.

Graesser, A., Jeon, M., Dufty, D. (2008). Agent technologies designed to facilitate interactive knowledge construction. *Discourse Processes*, *45*, 298-322.

Kintsch, W., & van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85,* 363-394.

Kroeger, S., Burton, C., & Preston, C. (2009). Integrating evidence-based practices in Middle science reading. *TEACHING Exceptional Children*, *41*, 6-15.

Magliano, J., Todaro, S., Millis, K., Wiemer-Hastings, K., Kim, H., & McNamara, D. (2005). Changes in reading strategies as a function of reading training: a comparison of live and computerized training. *Journal of Educational Computing Research*, *32*, 185-208.

McMaster, K., Fuchs, D., & Fuchs, L. (2006). Research on peer-assisted learning strategies: The promise and limitations of peer-mediated instruction. *Reading & Writing Quarterly*, *22*, 5-25.

McNamara, D., O'Reilly, T., Best, R., & Ozuru, Y. (2006). Improving adolescent students' reading comprehension with iSTART. *Educational Computing Research, 31*, 147-171.

National Center for Education Statistics. (2010, March 12) *The Nation's Report Card: The NAEP Reading Achievement Levels by Grade*. Retrieved June 25, 2010, from http://nces.ed.gov/nationsreportcard/reading/achieveall.asp

National Center for Education Statistics. (2002, June 19) *The Nation's Report Card: The NAEP Science Achievement Levels*. Retrieved June 25, 2010, from http://nces.ed.gov/nationsreportcard/science/achieveall.asp

Radcliff, R., Caverly, D., Hand, J., & Franke, D. (2008). Improving reading in a middle school science classroom. *Journal of Adolescent & Adult Literacy, 51*, 398-408.

Radcliff, R., Caverly, D., Peterson, C., & Emmons, M. (2004). Improving textbook reading in a middle school science classroom. *Reading Improvement*, *41*, 145-156.

Rogevich, M., & Perin, D. (2008). Effects on science summarization of a reading comprehension intervention for adolescents with behavior and attention disorders. *Exceptional Children*, *74*, 135-154.

Zimmerman, C., Gerson, S., Monroe, A., & Kearney, A. M. (2007). Physics is harder than psychology (or is it?): Developmental differences in calibration of domain-specific texts. In D. S. McNamara & J. G. Trafton (Eds.), *Proceedings of the Twenty-ninth Annual Cognitive Science Society* (pp. 1683 – 1688). Austin, TX: Cognitive Science Society. http://www.cogsci.rpi.edu/ csjarchive/ proceedings /2007/docs/p1683.pdf