Larissa is a 5th grader with a learning disability in the area of reading. She attends an urban school with a high number of students receiving free and reduced lunch, as well as a large population of students receiving special education services. Today, Larissa is participating in shared reading of a science book about planets in the solar system. Her class first predicted the content of the book based on text clues and brainstormed questions. They then added vocabulary words and definitions in their own language to the “Science Words/Everyday Words” chart posted in the classroom. The teacher, Mr. Henry, then modeled a text-paraphrasing strategy before the students’ turn to summarize the next passage. The next day, Larissa and her peers examined pictures of planets with accompanying fact sheets. In groups, they used the “data” about the planets to make comparisons between the planets. Different groups made statements such as, “Neptune is farther from the Sun than Saturn,” and “Venus’s composition is rocky just like Mars.”

Why All the Emphasis on STEM?

Many educational researchers have written about the need for students to gain a strong foundational understanding in science, technology, engineering, and mathematics (STEM). Most often, we hear about the need to expand the pipeline of students entering STEM fields (National Science Foundation, 2011). Having an understanding of STEM, however, is not only necessary for those who are interested in STEM careers, but is critically important for all citizens to be able to make informed decisions about the scientific and technical issues affecting their lives (Matthews, 2007). Despite this need for STEM literacy, students with disabilities have consistently underperformed in STEM coursework (AccessSTEM, 2007). There are many reasons for this underperformance, including the following:

• STEM instruction often focuses on abstract concepts (Brigham, Scruggs, & Mastropieri, 2011).
• Many STEM-related concepts are described through difficult vocabulary within complex expository texts (Lee & Erdogan, 2007).
• Teachers often focus on a rigid interpretation of the scientific method that involves complex, multistep problems with limited supports (Villanueva & Hand, 2011).
• The way schools schedule and organize instruction often limits integration of STEM because these
subjects are often taught in isolation (Breiner, Johnson, Harkness, & Koehler, 2012).

This combination of barriers to learning can disenfranchise students from science and other STEM fields. As a result, only approximately 5% of students with disabilities enter the STEM workforce (Leddy, 2010).

Unfortunately, we do not yet have a full understanding of how to best support diverse learners in meaningfully accessing STEM education. Many STEM content teachers, for example, still rely on didactic instruction, lab experiences, and STEM texts in their instruction (National Research Council [NRC], 2011) and do not ensure that these are accessible or appropriate for conveying the often abstract concepts within them. Other STEM content teachers rely on more authentic learning opportunities that center on inquiry learning and provide little explicit instruction to support the students’ open inquiries.

The swing of the pendulum toward inquiry, although certainly enhancing student engagement, has resulted, in many cases, in fewer opportunities for students to meaningfully engage in text and receive explicit instruction in the concepts presented within those inquiries. Special educators often face the need to balance these curricular expectations with the needs of students with disabilities. Therefore, the purpose of this article is to highlight evidence-based strategies that promote literacy-embedded STEM learning that special and general educators can implement in teaching students with disabilities.

We focus specifically on literacy-embedded STEM instruction for two reasons. First, as stated previously, many students struggle in STEM because of difficulty in accessing the language of STEM. Second, a growing body of literature connects language and disciplinary discourse with STEM learning. Simply stated, students’ STEM experiences facilitate language growth, which, in turn, enhances their understanding of STEM (Yore, Pimm, & Tuan, 2007). A cyclical relationship exists between STEM literacy and STEM learning.

What Is STEM Education?

The concept of STEM education translates to more than the subjects that make up the acronym (science, technology, engineering, mathematics). Researchers often refer to STEM in the context of K–12 interdisciplinary teaching. STEM education, in the larger view, is an approach to learning that
emphasizes student-centered, collaborative learning. The interdisciplinary approach that STEM offers gives students with disabilities and other struggling learners the opportunity to make sense of the world in a more authentic way instead of learning about STEM through isolated and de-contextualized facts (Basham, Israel, & Maynard, 2010). It is these authentic experiences that promote meaningful engagement in real-world applications of learning. A STEM curriculum and teaching approach can create learning environments designed to engage all learners in doing STEM (NRC, Committee on Development, 2000).

The role of special educators within this interdisciplinary approach to STEM can vary widely, depending on the grade level, content area focus, instructional setting, and the special educator's comfort with the STEM content. Special educators may co-teach collaboratively with the content teacher, provide small group or individualized explicit instruction, and engage students in supplemental activities that promote content understanding in the context of meeting both individualized goals and content standards.

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What Are the Connections Among STEM, Reading, and Content Literacy?

STEM education and reading instruction should be considered closely related in supporting content-related literacy, defined as the techniques that a novice reader can use to make sense of a disciplinary text (Shanahan & Shanahan, 2012). Throughout K–12 teaching and learning, STEM and reading both involve acts of inquiry through processes to discover, find out, and investigate (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007). Students who actively engage in both reading and STEM continually think through processes such as predicting, inferring, and questioning. In addition, because teachers usually present STEM content through nonfiction texts (including primary texts, reading textbooks, etc.), the ability to use reading and writing to acquire new content understanding is critical to students' success in STEM learning. Integrating reading instruction into STEM education helps students with disabilities by providing them with the tools needed to meaningfully access text materials that often pose significant barriers to their learning.

Providing Explicit Instruction in Content Literacy. To develop the content literacy of students with disabilities and other struggling learners, we must move beyond relying on students' independent reading of instructional texts for the dissemination of facts and abstractions. Instead, we should consider ways of integrating primary authentic texts as a critical component of learning. As students with disabilities and other struggling learners experience these texts, they often require explicit instruction in reading strategies to access these texts meaningfully (Faggella-Luby, Graner, Deshler, & Drew, 2012). Hence, when you consider how to support students with disabilities in STEM instruction, create opportunities for them to engage in authentic interdisciplinary STEM learning that includes reading primary texts supported by explicit reading instruction.

STEM Content Literacy, the Common Core State Standards, and Students With Disabilities. The new Common Core State Standards (CCSS) in both English language arts (ELA) and mathematics include strategies and approaches for building student content literacy. The ELA standards specifically address literacy in science and other technical subjects. For reading of nonfiction technical texts, the ELA standards call for students to pull out key ideas and details, to understand the craft and structure of texts, and to have an awareness of text complexity. For writing, the ELA standards focus heavily on writing arguments based on discipline-specific texts. Even the mathematics standards frame mathematical practices that develop students' content literacy. Some examples include constructing viable arguments, modeling with mathematics, and looking for and making use of structure.

A STEM education approach could help to accomplish the vision of the CCSS with their shared focus on deep content knowledge and student learning practices. K–12 STEM education could provide a curriculum that supports the development of core academic competencies of students with disabilities and other struggling learners through the integration of literacy, technologies, and engineering with mathematics and science (STEM with a content literacy integration).

Teaching Practices That Promote Literacy-Embedded Authentic STEM Learning

In this section, we offer recommendations that special and general educators can use for creating literacy-embedded STEM instruction that support students with disabilities.

Get to Know Your Students

No two students learn in exactly the same way; are motivated by the same activities; or struggle with the same concepts, ideas, or tasks. When working with any group of learners, the great variability among them quickly becomes clear (Center for Applied Special Technology [CAST], 2012). Therefore, the very first strategy involves learning as much as possible about your students including (a) their interests, (b) what they find difficult or scary about learning, and (c) what strategies they are currently using. Teachers can use several strategies to assess students' interests, their views on STEM careers, and the strategies
that they use to access difficult information. These include the following:

- Encourage students to draw pictures of STEM concepts and how these concepts apply to their lives. For example, 5th-grade students drew pictures of the work of engineers in which the teachers learned that most students had numerous misconceptions. Almost half of the students equated engineers with mechanics and only 10% drew pictures of women.

- Co-construct graphic organizers, such as a KWIL (What do I know, what do I want to know, and, later, what I have learned about the topic). The “W” provides a great deal of information about areas of interest to your students. This strategy allows you to learn what your students already know, find out what information they would like to learn, and provide a strategy for helping them document new information as they learn it.

- Conduct individual meetings with your students to learn whether they have concerns about upcoming STEM instruction and what strategies they have tried (successfully or unsuccessfully) to meet challenging learning situations. Often, students will be more comfortable sharing personal fears confidentially rather than in whole-group instruction.

Explicitly Teach and Embed Reading Strategies Into STEM Inquiries

When engaging in STEM-specific texts, general educators often assume that students can read the assigned materials without reflecting on whether the students have the necessary skills and strategies to effectively comprehend the text. This is especially true as students transition into secondary education. High school STEM teachers often think that they do not have the time or expertise to “teach reading.” Without explicit instruction to engage students in the active reading of texts, many struggling learners and students with disabilities may not be able to access vocabulary, text structures, and relevant background knowledge to support text comprehension and the construction of new knowledge (Faggella-Luby et al., 2012). As a special educator, you may often need to focus on supporting your students’ reading comprehension as part of active engagement in STEM literacy. One way that you can do so is by applying the literacy framework of before, during, and after (BDF) for each component of literacy. We recommend several strategies that include notions of BDF.

Before Reading. Before reading STEM texts, it is important to help students recall what they already know and frontload important vocabulary and concepts vital to comprehension.

- Preteach essential new vocabulary. Vocabulary targeted for frontloading should be carefully selected. The goal of frontloading vocabulary instruction is to provide essential meanings to concepts that hinder text comprehension. Frontloaded vocabulary should include explicit definitions in student-friendly language, defining characteristics of the concept, and examples and non-examples. For example, when Mr. Henry taught about planets he taught the students the vocabulary such as orbit, asteroid, and rotation and recorded these words on the “Science Words, Everyday Words” chart.

- Survey the text prior to reading. Students should learn to examine text features such as titles, headings, pictures, and captions, and then make predictions about what they expect to learn from the reading. Previewing text is known by many names, and includes strategies such as SQ3R (Robinson, 1970) and THIEVES (Zwiers, 2010), which represent acronyms to help students remember the text survey steps.

- Engage students in a quick write. Another strategy to activate prior knowledge is the quick write. Students are asked to focus on the topic for a few minutes by writing down what they already know about the topic. Quick writing activities also provide teachers with information about their students’ background knowledge and misconceptions about STEM content.

During Reading. Encourage students to self-monitor their comprehension of new material, use fix-up strategies to repair comprehension, and identify new vocabulary words important to comprehension during reading.

- Vocabulary during reading. Students should be taught how to proceed if they do not understand the vocabulary. For example, if students encounter an unfamiliar word, they could use strategies such as using text clues, referring to a classroom word wall, using the glossary, and seeking help to clarify critical vocabulary.

- Text structure. One aspect that makes STEM reading challenging is the use of multiple text structures to convey ideas. For example, one part of a chapter may describe the sequence of mitosis, while another part of a chapter might compare and contrast mitosis with meiosis. Alerting students to the multiple ways authors organize texts for different purposes should be explicitly taught to students. Zwiers (2010) recommended teaching students to identify different text structures by locating key words that alert students to the pattern. For example, the words “similar to” suggest the author is comparing two concepts.

- Paraphrasing. During paraphrasing, students are encouraged to restate the main ideas and important details in the readings in their own words (Hagaman & Reid, 2008). Putting ideas into their own words facilitates making connections to prior knowledge and experiences. It may also help integrate newly acquired knowledge with prior knowledge, a challenge for many learners, including those with disabilities.

After Reading. After reading, students should integrate newly acquired knowledge with existing knowledge. Strategies for supporting students’ after-reading comprehension include
learning logs and graphic organizers, in addition to vocabulary studies.

- **Vocabulary.** Students might select important concepts postreading to complete a semantic features study. For example, students might construct a chart that organizes the attributes of different kinds of plants, showing where to find various species for further analysis.

- **Learning logs.** Students might be encouraged to write in a learning log, not unlike the kinds of writing done by countless STEM professionals during project work. They might jot down important wonderings or new ideas generated from their reading.

- **Graphic organizers.** Both teachers and students can use graphic organizers to help students organize their thoughts on important STEM concepts.

Integrate Instructional Technologies Into STEM Inquiries

Instructional technologies available in most schools can support STEM content literacy in significant ways. Whereas in the past, teachers relied on text and labs to illustrate STEM concepts, now teachers have a wealth of digital resources, simulations, video games, and probeware that can enhance, clarify, and supplement STEM learning in a manner that is engaging and accessible to a wide range of learners.

**Simulations.** Simulations involve digital models of situations that allow learners to manipulate parameters as well as observe and interact with representations of processes that are otherwise invisible (NRC, 2011). Simulations provide ways for students to engage in STEM concepts virtually through simulated experiments. There are some concepts that are quite abstract and difficult to understand without "seeing" how they work. Students may struggle with concepts such as the differences between series and parallel circuits and how they can be used. By manipulating the components virtually through a simulation, they will gain a stronger foundational understanding of the differences between simple, series, and parallel circuits. As a special educator, you can integrate these simulations either into whole group instruction or into individualized instruction to support students. Examples of simulations include:

- **PhET:** These free, interactive simulations have been studied at the University of Colorado for both their design and use with students learning about physical phenomena. These simulations can be accessed at http://phet.colorado.edu/.

- **Gizmos:** These fee-based simulations offer opportunities for inquiry and exploration of a wide range of mathematical and scientific concepts. Teachers can search for simulations both by finding their state standards or the Common Core State Standards and matching simulations to the standards or by searching simulation by specific content search. These simulations can be accessed at http://www.explorelearning.com/.

Mobile Learning Applications.

With the increasing popularity of mobile technologies such as the iPad and Samsung Galaxy Tablet, there has been a proliferation of mobile

Strategies for supporting students' after-reading comprehension include learning logs and graphic organizers, in addition to vocabulary studies.

**Collaborative Reading Strategies.** A variety of collaborative reading strategies support students with disabilities. Two examples of collaborative reading strategies include reciprocal teaching and interactive reading guides.

- **Reciprocal teaching** is a method that includes predicting, clarifying, questioning, and comprehending texts in collaborative groups (Palincsar & Brown, 1984). Students are taught how to manage the processes involved. The importance of this strategy for students with disabilities, as well as struggling readers, is that this strategy actively involves each group member in engaging with the text.

- **Interactive reading guides** afford students the opportunity to collaborate meaningfully during the reading of a content text (Wood, 2002). Teachers prepare guides based on the texts students will read and code them regarding in which mode each task should be completed.

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learning applications that support STEM learning. These apps provide a broad range of learning experiences including simulations, vocabulary supports, literacy connections, and games that support STEM content learning. The following are a few well-designed iPad applications.
• *Frog Dissection* provides a virtual frog dissection that explores the inner workings of a frog. This application also provides extended content about frogs.
• *Journey to the Exoplanets* allows students to explore planets as they pilot a space shuttle through space.
• *Coaster Physics* allows students to design and operate their own roller coasters and see physics principles in action.

**Build on Authentic Learning Processes**

Authentic learning processes in STEM education expose real-life applications. Thus, authentic learning engages learners in the construction of knowledge through disciplined inquiry that has value beyond the school (Newmann, King, & Carmichael, 2007). Authentic learning strategies, such as inquiry and problem- and project-based instruction, are central strategies for teaching integrated STEM content and processes.

Along with these strategies, teachers are realizing that engineering design can be a powerful tool for authentic problem solving. Mehalik, Doppelt, and Schuun (2008) suggested that when attempting to teach within an engineering design framework, you should consider the following three phases:

1. Students explore the topic by brainstorming ideas about building a functional artifact.
2. Students put aside their initial constructions and consider a standard model developed by synthesizing class ideas. Students conduct systematic tests (controlled experiments) during this time.
3. Students go back to an open design process in which they incorporate ideas they have gained, or they can develop a completely new design.

These strategies provide pathways for students with disabilities and other struggling learners to engage in and learn about STEM in a flexible manner. The following are suggestions for supporting students with and without disabilities within this instructional framework:

• Create collaborative authentic learning environments that are meaningful to your students. Teachers, students—and STEM community partners—can work together as active learners to establish an authentic learning approach to curriculum and instruction. In this way, students learn how to solve real-world problems and apply their knowledge in creative and innovative ways; they thus create products, not just take tests (Newmann et al., 2007).
• Integrate scientific inquiry with engineering design processes. Engineering design is increasingly being viewed as a gateway to authentic learning that can support increased student understanding of STEM concepts (Benenson, 2001; Crismond, 2001; Kolodner et al., 2003). The National Research Council (NRC, National Academy of Science, 2009) argues that scientific inquiry and engineering design processes can be mutually reinforcing in classroom instruction. Both focus on solving problems and require creative thinking, communication, and collaboration. There is strong emerging evidence that through these instructional practices, we can increase diverse learners' achievement and increase their interest in STEM.
• Mousetrap vehicles, solar-powered devices, rocketry, or the design of structures such as bridges are authentic means of introducing STEM principles to students. Such approaches stimulate interest and increased learning in a growing number of students, many who may otherwise turn away from STEM (see Table 1 for STEM resources).

**Promote Collaborative Planning and Teaching to Promote Literacy-Supported Interdisciplinary STEM Instruction**

To truly promote STEM learning for students with disabilities and other struggling learners, there must be a
commitment to collaboration among content-area teachers, special educators, and other teaching staff that support struggling learners. In fact, the embedded reading strategies described here are often best implemented within a collaborative teaching environment. Collaboration leads to the following outcomes:

- Better generalization of instructional strategies across the content areas.
- More effective communication about students’ needs.
- Opportunities to develop and implement authentic, interdisciplinary STEM opportunities.

When considering ways of promoting collaborative planning and implementing literacy-embedded STEM instruction, consider the following suggestions:

- Communicate the benefits of integrating reading into the STEM disciplines. Remember that integrating comprehension and vocabulary strategies have been found to improve content area learning outcomes (Williams, Stafford, Lauer, Hall, & Pollini, 2009). The key is to decide on a few strategies and teach them explicitly.
- Begin with coplanning one or two authentic learning experiences that integrate explicit reading and inquiry and engineering design principles opportunities. By starting small, you give yourself opportunities to learn the instructional processes without the pressure of attempting to change your entire teaching pedagogy.
- Realize that collaborative relationships take time to develop. Open communication, coupled with problem solving, will support relationship building among teachers in the service of students’ academic learning (Pugach, Johnson, Drame, & Williamson, 2012).

**Final Thoughts**

Although the integration of authentic STEM learning and reading seems intuitive to some educators, in many classrooms, STEM and reading are viewed as having separate instructional objectives and benefits. In addition, STEM content teachers may see their job as providing content to students while viewing the job of the special educator as providing supplemental reading instruction when necessary. This article provides a rationale for integrating content with reading to support students with and without disabilities, as well as suggestions for integrating explicit reading strategies into authentic STEM experiences.

Focusing either on inquiry or explicit instruction alone is shortsighted and provides a limited view of what diverse learners need to be successful in rigorous STEM content. By integrating explicit instruction into authentic STEM activities, students can have opportunities to authentically engage in STEM learning, access content in a meaningful way, and have opportunities to improve their content-literacy skills.

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