STEM Education

Helping Students Succeed Within Secondary-Level STEM Content

Using the “T” in STEM to Improve Literacy Skills

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STEM: science, technology, engineering, and math courses. The words alone are challenging to many secondary students with specific learning disabilities. Add to these difficult concepts a sometimes bewildering, intertangled vocabulary and you get a set of challenges that many students find daunting. To this add frustrated teachers who may be using methods that aren’t effective (such as over-lecturing), who may have many students who are performing below grade level in literacy skills, and who may struggle to make STEM content relevant to the lives of their students.

Despite the fact that we have confirmed effective reading instructional practices for students who struggle at the elementary level, many students continue to have difficulty reading and comprehending grade-level text in Grades 4 through 12 (Biancarosa & Snow, 2004). This difficulty is especially true for adolescents with specific learning disabilities (SLD), because they continuously face complex academic challenges. These intertwined challenges can restrict learning and overall achievement (Deshler & Shumaker, 2006). Such complex challenges are prevalent in science, technology, engineering, and math (STEM) coursework, given the hefty demands of vocabulary terms and concepts (Therrien, Taylor, Hosp, Kaldenberg, & Gorsh, 2011), obtuse expository texts (Mason & Hedin, 2011), and subject-specific problems that need to be addressed through inquiry and other advanced cognitive processes (Lee & Spratley, 2010).

When faced with the responsibility of teaching adolescents with SLD who may be reading several grades below their peers, general and special educators can hardly be blamed for feeling overwhelmed. Teachers may struggle with determining which evidence-based reading strategies (e.g., vocabulary and comprehension strategies) are most appropriate for their students, as well as how to incorporate the strategies into instruction while keeping up the instructional pace. Thus, for practitioners searching for evidence-based strategies and ways to deliver those practices to help students succeed within secondary-level STEM content is to look at potential mismatches between common instructional methods and content demands. This article provides teachers with both alternative and emerging evidence-based approaches to address the challenges in STEM content areas while supporting content-specific literacy demands using instructional technology.

Identifying Mismatches: Instructional Methods and Content Demands in STEM Classrooms

Although there are surely more, we begin this discussion by discussing two significant mismatches between how STEM content at the secondary level is organized and taught, and the cognitive learning needs of students with SLD. Given these potential problems, we then introduce a new application of instructional technology that is intended to support improved instruction and student learning.

Mismatch 1: Instructional Delivery Methods Do Not Always Support Learning

The Endless Lecture. You are probably all too familiar with situations in which a 10th grade biology teacher, for example, delivers a 30- to 45-minute
PowerPoint-driven lecture with a large amount of on-screen text and complex images (i.e., diagrams of cells). In this hypothetical lecture, the teacher may "only" introduce one to three complex, multisyllabic vocabulary terms or concepts, but he or she is also likely to liberally use language that consists of an untold number of technical terms, concepts, formulas, and other jargon that may be completely unknown to the struggling learner. Students with SLD are unlikely to keep pace during these fast-paced lectures, and they may have trouble discriminating between important versus trivial details (Swanson, 2001).

This biology teacher may augment her lecture by assigning a 15-page textbook chapter as a homework assignment and primer for the next day's lesson. This scenario is not unusual, as textbooks play a dominant role in STEM instruction (Brigham, Scruggs, & Mastropieri, 2011). Unfortunately for the struggling learner, the same unknown science-specific language conventions and vocabulary terms that affect learning during oral lectures can restrict ability to read and comprehend textbooks and other text-based materials (Villanueva & Hand, 2011). As a result, the inability to comprehend text or keep pace during face-to-face instruction results in a perpetual cycle of failure within STEM and other secondary-level content coursework for many struggling students.

Basic Literacy Struggles. Many students with SLD in an area related to reading have limited basic literacy skills. Shanahan and Shanahan (2008) define basic literacy skills for adolescents as "decoding and knowledge of high-frequency words that underlie virtually all reading tasks" (p. 44). In fact, a common belief is that all secondary students (Grade 4 and above) are ready to shift from "learning to read" (i.e., decoding) to "reading to learn" (i.e., comprehension). The truth, however, is
that many students continue to struggle at a basic level, including decoding text laden with multisyllabic words, prohibiting their ability to access meaning in the upper-level expository texts they are presented within content area classes. Thus, students with SLD need individualized, evidence-based reading instruction to overcome deficiencies in their basic literacy skills (Edmonds et al., 2009; Vaughn et al., 2011).

Older students who struggle with reading must keep up with the complex concepts that are introduced across the content areas; however, they cannot always rely on their existing reading skills to access this information (Roberts, Torgesen, Boardman, & Scammacca, 2008). Therefore, secondary learners need evidence-based instruction in content area classes to improve students' ability to decode multisyllabic words, make sense of complex vocabulary, and attach meaning to facilitate learning in the content areas (Faggella-Luby & Deshler, 2008). In the next section, we present two key evidence-based approaches for accomplishing these tasks.

Mismatch 2: Content Demands That Overwhelm Student Cognition

Limited Relevance to Students' Lives.

STEM coursework often contains content that has no obvious real-world meaning to adolescents and is frequently abstract and laden with multi-step operations. In addition, some tasks require application of specific operations or rules for solving problems. These processes can strain the cognitive capacity of some learners when attempting to update or create new schemas in long-term memory (Swanson, 2001).

Consider the following example: A 9th grade mathematics teacher uses an overhead projector to demonstrate how to solve for x when working on polynomial equations. Although the basic skills needed to solve algebraic equations are usually not inherently complicated (e.g., addition, subtraction, multiplication, division), some students with SLD will either not have basic facts memorized, or take a longer time than their peers in recalling facts. The problem of slow retrieval of memorized content becomes problematic when, for example, teachers present abstract and multi-step algebraic equations to students. If students take too much time searching for memorized math facts or for specific steps to complete an operation, the students will have very little time and capacity to apply this information and solve novel problems. In addition, the teacher at the overhead projector is likely using mathematics-specific language to explain the problem's steps to students, which, as previously noted, is also a mismatch for how students with SLD best learn new and complex content. In sum, students with SLD who do not possess adequate background knowledge to anchor new instruction, and are not taught using evidence-based practices that explicitly support cognition are at significant risk for struggle and failure within STEM coursework.

Designing the Instruction Students Need. Despite the somewhat inherent complexity of STEM coursework, students with SLD need (and are entitled to) specially designed instructional supports intended to help bridge any gaps between their overall cognitive processing struggles and the demands of the curriculum (Hallahan, Lloyd, Kauffman, Weiss, & Martinez, 2005), which includes the ability to read and comprehend complex texts (Mason & Hedin, 2011). Specially designed supports in STEM classrooms can include applications of assistive or instructional technology, in addition to more traditional approaches to teaching and learning (e.g., explicit and direct instruction; Kennedy, 2011). Though a full treatment of the numerous established and emerging lines of research in this area is beyond the scope of this article, we encourage you to read Strangman and Dalton (2005) for a thorough discussion.

In this article, we describe an emerging application of instructional technology, called Content Acquisition Podcasts (CAPs; Kennedy, 2011; Kennedy, Newton, Haines, Walther-Thomas, & Kellems, 2012; Kennedy & Thomas, 2012). CAPs is a practical way to address the two mismatches noted previously. We describe how teachers and students can use CAPs in concert with evidence-based practices for improving literacy outcomes in STEM classes.

What Are CAPs?

CAPs are different from generic podcasts in that they sync visuals and audio together with strict adherence to Mayer’s Cognitive Theory of Multimedia Learning (CTML; 2009) and instructional design principles (2008). Mayer’s CTML (2009) offers teachers a practical framework for designing multimedia-based instructional materials that do not introduce undue levels of cognitive load; instead, these materials promote active cognitive processes needed for learning. Please see Kennedy & Thomas (2012) for a detailed discussion of how CAPs reflect Mayer’s principles.

Although CAPs are theoretically supported practices, they are merely a vessel for delivering instruction. Thus, CAPs must be infused with relevant evidence-based practices to be effective (Kennedy, 2011). For example, teachers can easily digitize content for
explicit or direct instruction for word learning, as well as powerful learning strategies such as the keyword mnemonic strategy. As you watch a sample CAP that teaches the meaning of the term *photosynthesis* (https://vimeo.com/49191997), take note of how the CAP includes evidence-based practices for vocabulary instruction. In short, CAPs reflect best practice in terms of supporting student cognition and can also provide strong instructional practice.

**Production Steps**

Although the prospect of creating new multimedia-based instructional materials for STEM instruction may be overwhelming, it is not beyond the reach of the dedicated special educator with a modern computer. To illustrate, the recommended software for creating CAPs is to use Microsoft’s PowerPoint (PPT). We have created a CAP on how to create CAPs using PPT, which is broken into two parts, and is available at http://vimeo.com/24179998 (part 1) and http://vimeo.com/24182724 (part 2). The production steps are also available in written form at http://people.virginia.edu/~mjk3p/. As you review these materials, note that the required knowhow with respect to technology is at a minimum, and the needed software and hardware are virtually certain to already be installed on every computer you own or use at school (assuming it was purchased within the past decade). With that said, mastering the technology side of the CAP production process is only half of the equation when preparing instructional materials for STEM classrooms. The second, and more critical element is preparing content so that it is tied to appropriate evidence-based practices that meet students’ cognitive processing needs.

In the remainder of this article, we present a four-part framework called CAP-4-STEM that is intended to help special educators prepare STEM content for packaging and delivery using CAPs. The CAP-4-STEM framework is integrated within a discussion of two key types of literacy instruction (i.e., word learning strategies and high-quality vocabulary instruction) that many students with SLD in an area related to reading need to be successful in STEM classrooms.

**Evidence-Based Methods for Improving Literacy Achievement at the Secondary Level**

**CAP-4-STEM Framework**

The CAP-4-STEM framework (see Figure 1) contains four key steps for preparing content to be inserted into a CAP. Step 1 is to identify the morphemes and any root words within a critical term or concept you want to teach. A morpheme is the smallest unit of language within a word that contains meaning, such as a prefix or suffix.

Step 2 is to prepare a student-friendly definition for each identified element of the word. This can be a challenge because many suffixes simply function to change the tense or plurality of a term; however, this is precisely the type of instruction students with SLD need to be successful (Reed, 2008).

Step 3 is to determine a student-friendly definition of the term in the STEM context being used. Users should be careful not to define new terms with other words requiring a definition; however, this can be problematic because many STEM terms and concepts require significant knowledge to be fully understood.

Finally, Step 4 is to select clear and vivid images that learners can use to remember meanings of the word parts and the term. You can find some royalty-free images at www.google.com/images or other search engines.

The steps of the CAP-4-STEM framework are inspired by, and interface with two essential approaches to teaching word meanings to students with SLD. The two approaches are (a) explicitly teaching word-learning strategies (Harris, Shumaker, & Deshler, 2011), which is a cornerstone of providing (b) explicit and strategic vocabulary instruction (Ehlers & Denton, 2008).

**Teaching Word-Learning Strategies**

Many secondary students struggle with reading multisyllabic words, which make up a majority of the text they encounter ( Archer, Gleason, & Vachon, 2003), especially in STEM classrooms (Brigham et al., 2011). These students may benefit from explicit instruction in syllabication strategies designed to improve reading of these complicated, often content-specific words (Bhattacharya & Ehri, 2004). This instruction typically involves teaching students the rules of syllabication and a flexible strategy to break words into meaningful parts, such as identifying prefixes, suffixes, and affixes (Archer et al., 2003). For example, students can learn the following strategy to decode and attach meaning to multisyllabic words (e.g., *malfunctioning*):

1. Circle the word parts (prefixes) at the beginning of the word. *mal-* in *malfunctioning*

2. Circle the word parts (suffixes) at the end of the word. *-ing* in *malfunctioning*

3. Underline letters representing vowel sounds in the rest of the word. *-al, -un, -ion,* and *-ing* in *malfunctioning*

4. Say the parts of the word. *mal-func-tion-ing*

5. Say the word fast. *malfunctioning*

6. Make it a real word.

To achieve maximum utility when providing students with word-level instruction in STEM classrooms, teachers should encourage students to learn specific strategies they can use when decoding unfamiliar terms with similar morphemes (Harris et al., 2011). This process is referred to as generative word learning strategies and is logical for use in STEM classrooms given the frequent use of Greek and Latin root words, as well as common prefixes and suffixes (Fang & Schleppegrell, 2008). The six-step strategy noted previously is an example of a generative approach to word learning.

What Technology Can Do. Although teachers have found many ways to
Promote students’ awareness of generative approaches to attacking words, instructional technology can help general and special education teachers prioritize this type of instruction. The use of instructional technology is not limited to certain time periods like during the school day or even the presence of the teacher. In addition, teachers can easily craft the content of instructional technology to only contain relevant information and to deliver evidence-based practices.

**Using CAPs to Support Generative Word Learning Strategies.** As we discussed earlier, two issues restrict success for students with SLD in STEM courses: ineffective instructional methods and cumbersome content demands. Teachers can address both issues by using instructional technology that meets standards for addressing student cognitive learning needs—technology that also delivers evidence-based instruction. Many content specialists explicitly teach students about common word parts (such as prefixes and suffixes and roots) as part of their vocabulary instruction; however, teachers may limit or skip such instruction when pressures mount to cover the curriculum.

To address this problem of practice, teachers may find the CAPs process helpful. When presented together, CAPs’ combination of images and synced narration constitute an instructional application of technology that teachers—and students, their parents, and other teachers—can use over and over in various settings and time periods. For example, students who did not show good progress on course assignments and other curriculum-based measures could be assigned to watch CAPs as part of remediation. Although CAPs would involve an upfront cost of production time, schools can create CAPs for the high-priority morphemes and vocabulary terms for entire courses. Previous research using CAPs (e.g., Kennedy, 2011) reports that this instructional tool can successfully package and deliver explicit and strate-
Vocabulary learning in STEM classrooms is extremely important because many terms and concepts are multisyllabic and do not have obvious anchors to students' existing knowledge.
SLD in an area related to reading or language processing: http://www.khanacademy.org/science/biology/v/photorespiration. An average student with SLD would likely be completely overwhelmed by the sheer volume of complex vocabulary, formulas, and the pace and duration (~17 minutes) of instruction. This is not to argue that Mr. Khan’s (and other similar) videos are of poor quality, or should not be used with children—as adult learners without disabilities we find them to be quite outstanding and serve a clear purpose. That said, we wish to make the point that when general and special education teachers do not carefully evaluate the language demands and other “looks and sounds” of multimedia instruction through the lens of how students with SLD will respond, the door is opened for students to be as cognitively overwhelmed as if the instruction was being provided with an inconsiderate in-class lecture. In contrast, CAPs provide a mechanism for packaging and delivering evidence-based instructional practices to students with disabilities using a proven method for promoting active cognitive processing. Please see Kennedy and Deshler (2010) for an explanation of how the cognitive characteristics of students with SLD are supported by Mayer’s design principles and a further discussion of other multimedia-based instruction that can help students with SLD make critical learning gains.

Final Thoughts

STEM courses can present unique challenges to students with SLD and others who struggle. These challenges are the result of complex textbooks and other reading requirements, cross-curricular learning opportunities, the need for strong background knowledge, and a lack of basic literacy skills. Teachers in the STEM areas may be aware that incorporating reading strategy instruction into their classes may be beneficial for helping all students access content. In addition, they know that incorporating word-learning strategies, such as strategies to decode and attach meaning to multisyllabic words, is important for helping students acquire the content knowledge they are responsible for covering. As special educators, we frequently play a key role in facilitating the design and delivery of this type of instruction.

Many STEM teachers design and use creative instructional tools, including assistive and instructional technology, to support students. Providing multimedia-based instruction reflects validated instructional design principles, but teachers of students who struggle need to pay specific attention (Kennedy & Deshler, 2010) to the individualized needs of students with SLD and other challenges. In other words, teachers should not assume that all instructional design is automatically individualized and capable of providing the type of direct, explicit, and evidence-based reading instruction reviewed in this article and noted in reviews and syntheses of literature (e.g., Edmonds et al., 2009; Wexler, Vaugh, Edmonds, & Reutelburch, 2008). STEM teachers can meet the individualized needs of students by incorporating ongoing, systematic, evidence-based reading instruction.

Through reflection, general and special education teachers can evaluate the extent to which their instruction is providing the level of support students with SLD need to be successful. If teachers find that instruction is a mismatch for students’ learning needs, one strategy that may be of assistance is CAPs. These supports are free to create and can be used in many flexible ways. (See box, “Online CAPs Resources” for a listing of additional resources.) However, any use of assistive or instructional technology should first be reconciled with respect to the goals and objectives of the student’s individualized education program (IEP) and be evaluated to determine the extent to which it can help students gain access to, and make meaningful progress in, the general education curriculum.

References
