CEI®
CREATIVE EDUCATION INSTITUTE®

WHY SVE WORKS

The Scientific Evidence that Grounds Its Design

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Why *SVE™* Works:
The Scientific Evidence that Grounds Its Design

The number of new vocabulary words in a science textbook
exceeds the number of vocabulary words
in the first year of a foreign language course.
— from Robert Yager (1983)

Science Vocabulary Essentials™ (SVE): History and Development

Creative Education Institute® (CEI)® has been in business more than 20 years. Its first product was *Essential Learning Systems® (ELS®)*, which has been continually improved both in content and technology, guided by ongoing scientific research on how struggling students can accelerate their learning and by the continuous action research conducted by CEI staff. CEI staff contribute every day to the Institute's database on what works in the thousands of labs with millions of students who have participated in CEI labs. *Mathematical Learning Systems® (MLS®)* was developed more recently. Although the content of mathematics requires a different program structure, CEI includes similar features in *MLS*, especially in lesson design and instructional strategies.

For many years, the CEI database of feedback from schools included the strong suggestions from many that CEI should develop a science intervention that emphasizes the development of scientific vocabulary and fluency. In 2008 that work began, and *Science Vocabulary Essentials (SVE)* for grades 3-8 was launched in summer 2009.

The CEI development team made a decision early in 2008 to use the powerful and effective learning engine in *ELS* for the design of *SVE*. Instead of teaching students words according to the sound patterns, as is done in *ELS, SVE* teaches sets of scientific words and terms according to meaning or thematic patterns. *SVE* students learn how to decode scientific words or terms, as well as how to pronounce them, spell them, define them, and use them in context, just as students do in *ELS*.

SVE differs from *ELS* in that it can operate with little teacher involvement in the back of a classroom or in an independent study situation, while *ELS* requires a lab setting with a focus on teacher engagement in coaching and monitoring student learning. The *SVE* teacher needs only to select the lesson or lessons for each student and assign him or her to one of the "sequences" or sets of lesson tasks. Sequences were designed for mainstream or advanced learners, as well as for those who struggle to learn—typically economically disadvantaged, learning disabled, and/or limited-English students.

The program's learning manager keeps track of lessons completed, levels of mastery, time-on-task, and other information that can be printed to document student progress.

Purpose of This Study

The purpose of this study is to provide educators with the scientifically-based and other research evidence in which *SVE* is solidly grounded—its content, lesson model, instructional features, and assessments. According to guidance documents published by the United States Department of Education, when the components of an intervention or supplementary program are grounded in scientifically-based research, then the program itself can be said to be grounded in scientific evidence (United States Department of Education, 2003; United States Department of Education, Jan. 7, 2004). This study will, therefore, document the scientific evidence underlying each product feature.

Need for *SVE*

CEI pursued the development of *SVE* because of the documented need for such a standards-aligned program that would provide efficient and effective instruction in science vocabulary. Struggling learners, whether economically disadvantaged, learning disabled, or limited in English proficiency, typically have weak vocabularies in general—and especially in the technical vocabulary of science since many of the words and terms are not used in everyday English. Even when those words are used, such as "matter," the meaning of the word is something entirely different from what it is in a science context.

Marzano, Kendall, & Gaddy's 1999 remarkable publication of *Essential Knowledge: The Debate Over What American Students Should Know* includes an extensive discussion of the research basis for including attention to vocabulary: "The critical relationship vocabulary has to reading in particular, and learning in general, explains why some students have great difficulty in school from the day they first walk through the classroom door" (p. 143). They cite scores of research findings that led Marzano & Marzano (1988) "to assert that vocabulary instruction should be a focal point of education, especially for students from more disadvantaged backgrounds" (p. 143). Another study they cite from Stahl and Fairbanks (1986) "indicates that student achievement will increase by 33 percentile points when vocabulary instruction focuses on specific words that are important to what they are learning" (p. 147). They conclude that "teaching vocabulary provides educators with an efficient way to expose students to the content within all the standards and benchmarks identified by subject-matter experts" (p. 148).

Vocabulary is, of course, one of the five critical components of reading instruction identified by the National Reading Panel (2000). Other researchers also strongly concur

that teaching vocabulary leads to gains in reading comprehension across the curriculum (Bruer, 1993, p. 190; Snow, Burns, & Griffin, 1998, p. 322; Adams, 1990, p. 146; Kamil, 2004, p. 10; Lehr, Osborn, & Hiebert, n.d., p. 20; and Mercer & Mercer, 2005, p. 289) and is critical to schools' efforts to close the achievement gaps (Hart & Risley, 1995, p. 160; Graves & Watts-Taffe, 2002, p. 145; and American Educational Research Association, Winter 2004, p. 2).

Vocabulary is also important in the content areas, including science. Marzano (1998) notes that "At a practical level, it is fairly obvious that students must understand a certain amount of the basic vocabulary in a subject area before they can understand facts, generalizations, and concepts within a content area" (p. 29).

Those Who Struggle to Learn

CEI has always focused on the needs of students who struggle to learn—typically the economically disadvantaged, those with learning disabilities (including dyslexia), and those who are learning English as a second language. Its interventions provide the prerequisite and foundational knowledge and skills that these children need in order to access the standards-based curriculum at grade-level, as well as the content that research identifies that typically causes students to have difficulties.

The low performance of students all over the United States on science assessments is in large part due to a lack of scientific vocabulary, and especially is lacking in the three broad categories of students who struggle.

Wolf (2007) notes that "the sheer unavailability of books" among students from impoverished environments "will have a crushing effect on the word knowledge and world knowledge that should be learned in these early years" (p. 103). She continues:

> The Canadian psychologist Andrew Biermiller studies the consequences of lower vocabulary levels in young children. He finds that children who come to kindergarten in the bottom twenty-fifth percentile of vocabulary generally remain behind the other children in both vocabulary and reading comprehension. By grade 6 approximately three full grades separate them from their average peers in both vocabulary and reading comprehension; they are even more dramatically behind children whose vocabulary in kindergarten was at or above the seventy-fifth percentile. In other words, the interrelatedness of vocabulary development and later reading comprehension makes the slow growth of vocabulary in these early years far more ominous than it appears when viewed as one unfortunate phenomenon. Nothing about language development has isolated effects on children (p. 103).

Mercer and Mercer (2005) point out that children with learning disabilities typically have poor vocabularies:

> Developmental delay in word meaning (semantics) is observed in youngsters who use or understand a limited number of words. . . . The student with retrieval difficulties often attempts to participate in classroom discussions but has no apparent response when called on to answer. Vocabulary difficulties may be evident in an inability to use specific words when describing objects or events (e.g., "that thing over there" or "the thing to use to write with") (p. 215).

According to the American Educational Research Association (2004), ELLs "will never catch up with native speakers unless they develop a rich vocabulary" (p. 2). They continue:

> Native speakers typically know at least 5,000 to 7,000 English words before kindergarten—a huge vocabulary, as anyone who has struggled to learn a second language knows. English-language learners not only must close that initial gap, but also keep pace with the native speakers as they steadily expand their vocabularies (p. 2).

Hill and Flynn (2006) draw similar conclusions:

> Even though ELLs are taught vocabulary as soon as they enter U. S. classrooms, they still lag significantly behind their English-speaking peers. McLaughlin and colleagues (2000) report that over time, an enriched vocabulary program can close the gap in vocabulary knowledge and reading comprehension between ELLs and English-dominant students (p. 27).

Klingner and Geisler (2008) note in a summary of research that

> How to assist ELLs increase their vocabularies is one of the greatest challenges their teachers face (Antunez, 2002). Vocabulary knowledge affects fluency as well as comprehension (Beck, McKeown, & Kucan, 2002). It is not uncommon for ELLs to be able to decode words without understanding what they mean (i.e., word calling) (p. 63).

Sadly, there are many children who suffer multiple challenges in learning:

> . . . the problems faced by struggling readers are exacerbated when they do not speak English as their first language, are recent immigrants, or have learning disabilities. Indeed, a struggling reader may fit all three of these descriptions, making intervention a truly complicated proposition
> (Biancarosa & Snow, 2004, p. 8).

Standards-based Content

Both No Child Left Behind (NCLB) and Individuals with Disabilities Education Act (IDEA), plus the laws and policies of almost all states, mandate that schools teach standards-based curricula, and from these established standards the various state assessments and even the National Assessment of Educational Progress (NAEP) tests are derived. Publications of the standards, whether from professional organizations or from state departments of education, almost always preface their compilations with statements that their standards are grounded in research. For example, the Texas Education Agency (2001, p. 5) states that their Texas Essential Knowledge and Skills (TEKS) "is a comprehensive research-based instructional program for grades k-12." Using this rationale, then, the content of a curriculum program is considered "research-based" to the extent that it is correlated with the research-based standards.

SVE is, therefore, standards-based. Lesson words are taken from standards documents from states, from districts surveyed, from commonly adopted science textbook glossaries, and from science books published for children. Since science standards are typically adopted in grade-level bands, there is a predictable overlap of many words from elementary lists into the middle and high school lists.

Science Vocabulary and Academic English

English-language learners are among the subgroups with critical needs to learn "academic English," including the content vocabulary to understand instruction and the assessment items (Barone, 1998, pp. 62-63). Jiang and Kuehn (2001) summarize some of the research as follows:

> Many ESL professionals have realized that general English proficiency is not all that ESL students need in order to succeed in mainstream courses. They also need English academic language development. Language proficiency is "only a means to an end: the critical outcome . . . is how well (students) succeed in school" (Saville-Troike, 1984, 217). According to Flowerdew (1994) and Wang (1996), educators and researchers generally agree that low proficiency in academic language and the distinctive type of English used in classrooms and in textbooks are contributing factors to academic failure among language minority and at-risk minority students (Wright & Kuehn, 1998) (p. 2).

Francis, Rivera, et al. (2006a) published an extensive study on the issue of academic English as it relates to learning and its importance for ELL programs:

> Mastery of academic language is arguably the single most important determinant of academic success for individual students. While other factors

> (e.g., motivation, persistence, quantitative skills) play important roles in the learning process, it is not possible to overstate the role that language plays in determining students' success with academic content. Proficient use of—and control over—academic language is the key to content-area learning (p. 7).

In a follow-up paper, they note:

> Academic vocabulary is central to text and plays an especially prominent role in the upper elementary, middle, and high school years as students read to learn about concepts, ideas, and facts in content-area classrooms such as math, science, and social studies. In doing so, ELLs encounter many words that are not part of everyday classroom conversation (p. 6).

There is a difference, of course, in ELLs who have rich educational backgrounds in their native language when they come to the United States and those who come without any or very little prior schooling. Snow (2006) explains:

> . . . classroom teachers are unanimous in noting that children who arrive in the United States with strong first-language vocabularies have little difficulty in acquiring English words. The mechanism widely suggested for this phenomenon is that knowledge of those concepts need not be reacquired; all that is needed is new labels for those concepts already present. In other words, conceptual knowledge is available in the first language and facilitates vocabulary acquisition in the second language (p. 638).

Laplante (1997) includes vocabulary instruction as one of the most important activities in a science program. In his research summary, he wrote:

> Students have to develop an appropriate level of proficiency with academic language or what Cummins calls a "cognitive-academic language proficiency" (Cummins & Swain, 1986, p. 15). This proficiency is distinct from the proficiency with social language they might already possess (Burkart & Sheppard, 1995). Even for language majority learners, the task is difficult to manage without specific language-related instruction (Rutherford & Ahlgren, 1990). For second language learners, it is only achievable through specific language related instruction (p. 66).

He adds, "Considering the large number of technical terms used in science, it is unrealistic to expect students to acquire them without any formal teaching in a purely communicative context" (p. 70).

ELLs are not the only students who require intensive instruction in academic science vocabulary in order to be successful. The reality, of course, is that learning the highly

technical words and terms found in any science course is a challenge for almost all students. Milligan and O'Toole (1969) made their observations 40 years ago, and the amount of science that is now required in American schools has grown exponentially in that time: "The importance of early systematic effort to build children's science vocabulary cannot be overestimated. Science educators regard the development of science vocabulary imperative" (p. 86).

SVE for grades 3-8 includes over 3000 science words/terms in 391 lessons. The words are grouped thematically, much as they would appear in a textbook unit, under the broad headings of How We Learn, Earth Science, Life Science, Physical Science, Science Processes, and Technology. A set of *SVE* orientation lessons describes for the student how the cognitive and neuro-scientists explain how we learn and how we remember. The Science Processes level is a focus on morphology, including 44 lessons on the prefixes, suffixes, and root words commonly found in scientific words and terms.

Knowing a Word

The goal of *SVE*, just as it is for *ELS* and, for that matter, all instruction, is to move new information and skills into long-term memory as efficiently as possible so that it can be retrieved rapidly and accurately at will and applied to new situations. One of the theories about how that is done is called the "levels-of-processing framework," originally proposed according to Sternberg (2003), by Fergus Craik and Robert Lockhard (1972) (p. 158). This framework sees knowledge storage along a continuum "in terms of depth of encoding" (p. 159). In other words, "the deeper the level of processing, the higher, in general, the probability that an item may be retrieved" (p. 159).

The levels-of-processing framework includes three levels: physical, acoustic, and semantic. The physical level includes "visually apparent features of the letters." Sound combinations associated with the letters is the basis for the acoustic level. The semantic level has to do with the "meaning of the word" (Sternberg, p. 159). These concepts relating to depth of processing are the grounding for both *ELS*'s and *SVE*'s instructional tasks, which are called SHARE—See, Hear, and REspond.

SVE incorporates all three processing levels in an attempt to embed the lesson content into long-term memory as effectively and efficiently as possible. Students learn to decode each word or term, to spell it, to pronounce it, to associate it with a graphic image, to define it, and to use it in context. Lehr, Osborn, and Hiebert (n.d.) explain that "Knowing a word by sight and sound and knowing its dictionary definition are not the same as knowing how to use the word correctly and understanding it when it is heard or seen in various contexts (Miller and Gildea, 1987)" (p. 3).

One of the debates in the development of *SVE* was whether to expect students to learn to spell the scientific vocabulary—or just learn to decode and define the words or terms. The research indicates that requiring mastery in spelling is important for a student really to know a word. However, because some teachers said they wanted an option, the program includes a provision that will allow a student simply to highlight a correct spelling rather than to type the correct spelling, as determined by the teacher. For virtually all students, CEI recommends that the student be expected to learn to spell to the mastery level.

It is important to remember that *SVE* is recommended as a supplementary program in the science classroom. It provides the explicit, systematic instruction that is important in the direct teaching of vocabulary, as opposed to incidental learning that occurs in other experiences, both at school and in the world. Both are important. Wood (2001) points out that "neither explicit instruction of a specific subset of word meanings nor incidental learning of vocabulary through literacy practices, such as extensive reading, is a sufficient strategy for vocabulary learning when used exclusively." Instead, she recommends that "rich learning environments that promote deep understandings of words and their semantic relationships are best created by applying both approaches in concert" (p. 4).

Lesson Design

Direct (Guided) Instruction. There is an overwhelming amount of research indicating that direct instruction (or guided instruction) is the most efficient and effective form of lesson design, especially for struggling learners.

A comprehensive review and synthesis of those studies was published in 2006 by Kirschner, Sweller, and Clark. "Direct instructional guidance" is defined in the study as "providing information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture" (p. 75). In contrast, examples of the "minimally guided approach" (also called "discovery learning," "problem-based learning," "inquiry learning," "experiential learning," or "constructivist learning") include "science instruction in which students are placed in inquiry learning contexts and asked to discover the fundamental and well-known principles of science by modeling the investigatory activities of professional researchers. . . . (p. 76). The conclusion of the researchers follows:

> The past half-century of empirical research on this issue has provided overwhelming and unambiguous evidence that minimal guidance during instruction is significantly less effective and efficient than guidance specifically designed to support the cognitive processing necessary for learning (p. 76).

They note that "Controlled experiments almost uniformly indicate that when dealing with novel information, learners should be explicitly shown what to do and how to do it" (p. 79). Connor, Rice, Canto, & Kaya (n.d.) concur: ". . . specific types of science instructional activities, such as inquiry-based or hands-on science activities, are less opportune for children with weaker vocabulary skills" (p. 1). (See the discussion on "direct instruction" in *Why ELS Works: Its Scientific, Theoretical, and Evaluation Research Base* available on CEI's webpage for more information.)

The steps of direct or guided instruction, according to the Alliance for Curriculum Reform and the Educational Research Council (1999), are defined as follows:

1. daily review, homework check, and, if necessary, re-teaching;
2. presentation of new content and skills in small steps;
3. guided student practice with close teacher monitoring;
4. corrective feedback and instructional reinforcement;
5. independent practice in seatwork and homework with a high (more than 90 percent) success rate; and
6. weekly and monthly reviews (p. 14)

SVE incorporates the steps of that direct or guided instructional approach. Students are introduced to the lesson words in the SHARE tasks (or primary tasks). The voice of the tutor pronounces each word a number of times, modeling the correct pronunciation and spelling. Words are presented in sets of eight, a number within the range that cognitive scientists recommend. SHARE includes guided practice in three modalities—visual and auditory, with kinesthetic responses. The tutor's voice provides frequent corrective feedback.

Students are then engaged in a variety of independent practice and assessment tasks that enable the student to learn the words or terms to a mastery level. The lessons assigned to the student enable appropriate sequencing of tasks so that the student can achieve a high level of mastery. Teachers and students have access to the reports so that they can keep track of lessons completed, time-on-task, and words mastered.

Lesson Sequences. Three different lesson sequences are available: Endeavor, Discovery, and Atlantis (names of United States space shuttles). Endeavor is for students who need minimal practice or reinforcement to master the terms. The second, Discovery, is for average students who are already able to access the grade-level science standards and curriculum and just need adequate practice to master new vocabulary. The third, Atlantis, is for students who struggle—

usually the economically disadvantaged, learning-disabled, or second-language learners. These students typically need more accommodations and more practice time. The sequences differ in the number of tasks to be completed, the order in which they are completed, and the number of times they are required, so, of course, there are time variations. CEI anticipates that the Endeavor sequence will require approximately ten minutes to complete, the Discovery sequence fifteen minutes, and the Atlantis sequence twenty minutes.

Time-on-Task. The amount of time that students are engaged in the instructional activity is also a part of the lesson design. Teachers report that less and less time has been allocated to science at the elementary level in recent years due to the emphasis on reading and mathematics in No Child Left Behind (NCLB) (Asimov, 2007, p. 1). In 2008 states were required under NCLB to add at least one science assessment at the elementary level, so teachers at grades 3-8 have been forced to scramble to find enough time to teach the foundational concepts and skills and to prepare students for a rigorous assessment.

The Alliance for Curriculum Reform (1995) documented more than 130 studies that "support the obvious idea that the more students study, other things being equal, the more they learn." They added that "It is one of the most consistent findings in educational research, if not all psychological and social research" (p. 11). So time is incredibly important in students being able to learn the science they need and to be able to meet the challenges of huge numbers of new science vocabulary words and terms that are introduced every year. (See the research findings on active engagement and time-on-task that are delineated in *Why ELS Works: Its Scientific, Theoretical, and Evaluation Research Base* for more information.)

Narrowing the achievement gap through accelerated learning is sometimes an over-whelming expectation for schools. To do so requires appropriate interventions, but it also requires additional time on task. Torgesen, et al. (2004) write that "The amount of instructional time learners need to make educationally significant progress is estimated in the USA to be at least 100 hours of instruction to make progress equivalent to one grade level" (p. 7). Second-language and learning-disabled students may require even more time.

SVE lessons are short and can be completed in 10-20 minutes, depending on the individual student. Students who need more time to complete assigned lessons may need to work before school, during lunch breaks, in after-school sessions, or in Saturday sessions to master the required vocabulary. Summer programs could also make good use of *SVE* to prepare students for the next year's science course—or to master all the terms that were introduced the previous year.

The teacher's goals will influence how the lessons are assigned and to which students, as well as the time required to complete them. CEI envisions the following possible applications:

1. pre-teach vocabulary and essential concepts before a unit is taught—especially important for English-language learners (ELLs) and perhaps children with learning disabilities or children who are economically disadvantaged;

2. reinforce the teacher's instruction, providing a review of critical concepts and vocabulary for all students;

3. use *SVE* as an intervention for struggling learners—those who need significantly more practice and repetition in order to learn the plethora of new vocabulary words that are introduced in each year of science instruction;

4. review for teacher tests/assessments;

5. review and practice for benchmark tests and state assessments in science;

6. enrich the learning of gifted/talented science students in lower grades than the grades where the content is typically introduced.

Computer-assisted Instruction. The preponderance of evidence in scientifically-based research substantiates the positive role of computer-assisted instruction in teaching vocabulary and other basic skills. Among the findings are that computer-assisted instruction:

1. facilitates more student-centered classrooms

2. is more effective than traditional methods

3. is more effective than use of printed materials alone

4. permits individualization

5. serves to mediate students in their zone of proximal development

6. assists students with learning disabilities to learn better

7. assists ELLs to learn better and more quickly

8. encourages more time on task

9. actively engages students

10. is motivating

11. develops fluency

12. facilitates multi-sensory processing

13. provides opportunities for adequate and varied practice

14. results in greater gains in variety of basic skills

15. is effective with a variety of at-risk learners, including those with dyslexia

(For documentation and analysis of the research behind these findings, see the sections on computer-assisted instruction in *Why ELS Works: Its Scientific, Theoretical, and Evaluation Research Base*.)

According to Blachowicz, Beyersdorfer, & Fisher (2006),

> Research on good vocabulary learning suggests that to develop vocabulary knowledge it takes:
>
> - a word rich environment
> - active, motivated engagement on the part of the learner
> - multiple exposures to and ways to access words and both contextual and definitional information about words; and
> - the development of independent learning strategies.
>
> With the increase in the time learners spend with technology and the increased access to technology (NCES, 2003), educational researchers see natural links between the points just enumerated and what technology can provide and facilitate. Technology can provide an interactive, motivating textual environment where strategy use is required and multiple exposures to vocabulary and vocabulary meanings are provided (pp. 341-342).

Another study by Baker, Simmons, Kameenui (n.d.) summarized the findings as follows:

> Two recent studies have examined the effectiveness of computer-assisted interventions for increasing knowledge of individual words. Three features, in particular, seem to make computer-assisted interventions attractive. First, such interventions require less direct teacher time than teacher-led instruction. Second, they have the potential to individualize instruction and facilitate the alignment of instructional techniques and vocabulary goals. Third, they have the potential to systematically imbed important instructional design features within the intervention framework, including systematic review, instructional scaffolding, and integration across academic areas (p. 13).

CEI's commitment to keeping students focused by eliminating as many distractions as possible is also evident in *SVE*. The International Dyslexia Association (2002) advises developers to "Block out extraneous stimuli" (p. 2). Babbitt (2004) concurs: "Most students with learning disabilities are distracted by too much stimuli coming at them at the same time. Moreover, cluttered screens often distract from the concept or procedure being studied" (p. 2). (See CEI's *Why ELS Works: Its Scientific, Theoretical, and Evaluation Research Base* for a more thorough analysis of the research on computer-screen design.)

SVE is designed so that the teacher can soften or totally eliminate the background themes as a method of individualizing instruction for some students with learning disabilities, but also for any student who is easily distracted by extraneous visual stimuli.

Instructional Strategies

SVE includes the same instructional strategies as *ELS* and *MLS*:

1. multi-sensory processing strategies,
2. high levels of individualization and differentiation,
3. adequate practice and repetition for the student to achieve mastery,
4. fluency development,
5. immediate, corrective feedback, and
6. chunking/cluster the lesson words into thematic groupings.

Study after study has found these to be the most effective features of an intervention program for struggling learners, as well as sound science to guide instruction for any student. (For documentation and analysis of the research behind these specific instructional strategies, see the specific sections on each one that are found in *Why ELS Works: Its Scientific, Theoretical, and Evaluation Research Base* and *Why MLS Works: Its Scientific, Theoretical, and Evaluation Research Base*.)

Multi-sensory Processing. *SVE* utilizes the same multi-sensory approaches to instruction as do *ELS* and *MLS*. Information is presented auditorily and visually, and the learner responds kinesthetically. The International Dyslexia Association (2000) strongly recommends this approach: "Multisensory teaching is simultaneously visual, auditory, and kinesthetic-tactile to enhance memory and learning" (p. 1). Herrell (2000) agrees:

> The use of multiple intelligences strategies supports the students' learning of new materials because it allows them to use the processing systems in which they integrate knowledge most effectively. By providing multiple ways for the students to demonstrate their understanding, their confidence in their own abilities is fostered and their anxiety is reduced (p. 144).

Snowling (1987) is one of many researchers who study dyslexia to recommend the use of multi-sensory learning: "It is good practice to encourage dyslexics to use all their senses during learning—to rely upon their strengths to compensate for and circumvent their weaknesses" (p. 147).

Willis (2006) adds the following conclusion for learners in general, not just for those with learning disabilities:

> The more ways that something is learned, the more memory pathways are built. This brain research discovery is part of the reason for the current notion that stimulating the growth of more dendrites and synaptic connections is one of the best things teachers can learn to do for the brains of their students (p. 3).

Then she adds:

> The more regions of the brain that store data about a subject, the more interconnection there is. This redundancy means students will have more opportunities to pull up all those related bits of data from their multiple storage areas in response to a single cue. This cross-referencing of data

> strengthens the data into something we've learned rather than just memorized (p. 4).

These findings among many others ground CEI's decision to teach multiple aspects of a word: shape, association with a visual cue, pronunciation, spelling, definition, and use in context. Each of these pieces of knowledge is stored in a different part of the brain, so there are multiple storage areas that are activated when a word is recalled—making the learning deeper and more meaningful.

The presentation of each new vocabulary word is accompanied by a visual cue—a photograph, drawing, or graphic. Again, this decision is research-based. Adams (1990) found that "In general, information that is illustrated tends to be better remembered, particularly at the level of details" (p. 367).

Individualization/Differentiation. *SVE* includes three lesson sequences that facilitate individualization and differentiation. (See previous discussion of sequences under "Lesson Design.") Each student will, then, have a lesson designed to meet his or her needs.

Another way that the program is individualized is in the assignment of lessons. The teacher has total control over those assignments, so he/she can allow some students to skip lessons or to use the program only for review, while other students may be required to repeat lessons as needed for mastery. CEI envisions as well that some teachers will use *SVE* with gifted/talented students so that they can start moving ahead with the challenging vocabulary presented.

The *CEI Learning Manager (CLM)* will also allow the teacher to speed up or slow down some presentations and to soften or eliminate the thematic screens if they are likely to be distractions for some learners.

Practice/Repetition. Good supplemental and intervention programs include enough practice activities so that any student can achieve mastery. They also include varied practice, presenting the lesson words in varied ways for deep-level encoding and in prompting recall and application of the learning in a variety of ways. CEI, just as it has done for *ELS* and *MLS*, has included an abundance of practice tasks and a variety of learning tasks in the structure and design of *SVE*.

It is probably impossible to over-emphasize the critical importance of adequate practice and repetition in learning anything, including vocabulary. Adams reported in 1990 that "the number of times that children encounter a word is a strong predictor of how well they will learn it" (p. 133). In 2004 the National Study Group noted that "Research tells us that a powerful way to promote long-

term retention and transfer is to allow students to practice retrieving previously taught material from long-term memory" (p. 16). Another national organization, the Alliance for Excellent Education (2004), found that "Repetition is essential for increasing vocabulary" (p. 3). The National Reading Panel emphasized that "Repeated exposure to vocabulary items is important for learning gains" (2000, p. 4-4).

> Researchers have also been interested in how much is enough practice, and, of course, the answer varies according to the individual learner. According to Ghadirian (2002), "the minimum number of exposures necessary for learning is dependent on the student's prior vocabulary size, the reasoning being that if the reader is familiar with the words surrounding the word in question, then the exposure will lead to better acquisition" (p. 162).

A general finding is that "more encounters with the words produced more learning" (Graves, 2007, p. 69). Ghadirian (2002) found that, on average, "a word needs to be encountered at least five times in order to be well retained" (p. 149). Samuels (2002), however, found that "students who encountered 10 repetitions of a word while reading acquired more word knowledge than did students who encountered the same word only twice." And Graves reported that "McKeown et al. (1985) showed that 12 encounters produced stronger results than 4 encounters and that students who also used the words outside of the classroom learned more fully than those who did not" (p. 69). Folse's (June 2006) research on teaching vocabulary to second-language students found that "The results of this study show the value of a vocabulary exercise that requires multiple encounters with or retrievals of the target words" (p. 287). He concluded:

> The current study indicates that doing multiple target word retrievals in an exercise, no matter how superficial the exercise may seem, is a stronger and more facilitative factor in L2 vocabulary learning than the purported deeper professing or involvement load that writing original sentences with new L2 vocabulary may offer (p. 287).

Fluency Development. Fluency, defined as rapid and accurate recall, is one of the things that CEI's programs do best, and that emphasis is also included in *SVE*. The design of SHARE activities includes every aspect of the word to be learned—the shape of the word, the spelling of the word, a visual cue, the pronunciation of the word, the definition of the word, and the use of the word in context. Therefore, when a student learns a word, several connections are established in the brain, enabling the student to recall everything he or she

knows about the word. The mastery criteria are set at very high levels so that the recall will be highly accurate, as well as rapid.

Fluency is well established as one of the most important influences on comprehension. Science texts can be extremely difficult, if not impossible, for some students to read—if the students are not already familiar with the very technical vocabulary that is prevalent.

Immediate Corrective Feedback. *SVE* students receive ongoing immediate and corrective feedback on their responses to the program activities. Research finds that such feedback is critical since without it students sometimes practice making errors. Then they must both "unlearn" those errors and start over in learning the correct information, which greatly confuses and slows down learning.

Feedback is also very important in keeping students motivated. The programs are structured for high success rates, and the ongoing positive, nonjudgmental feedback keeps students working—and learning.

Chunking/Clustering. In *ELS* the words are grouped by sound patterns. *SVE* uses essentially the same instructional methodology as *ELS*, except that it groups words by theme. Cognitive psychology has established that using chunking/clustering strategies is a way to accelerate learning and also to improve memory.

Assessments

Each *SVE* lesson concludes with a Mastery Spelling Test and a Mastery Vocabulary Test. (The spelling test may require students to type the correct spelling of each word or term, or the teacher may allow the student simply to highlight the correct word from a group of three similarly spelled words.) These tests provide teachers with information that can be used for data-driven decisions:

1. whether to change a student's sequence
2. whether to change lesson parameters
3. whether to require a student to do a lesson more than once
4. whether a student needs more or less review
5. as daily or test grades
6. as indications of needs for test preparation
7. as information for students and/or their parents
8. as formative data to chart student progress toward standards mastery

Summary/Conclusions

When the research reports on *ELS* and *MLS* were written, the researchers carefully "deconstructed" each program, listing the features of the content being taught, the lesson design, and the instructional strategies. A similar methodology was employed for this report on the scientific evidence grounding *SVE*.

SVE content differs from *ELS* in one significant way. *SVE* focuses on standards-based content—the scientific vocabulary that students in grades 3-8 are expected to master in order to demonstrate mastery of the standards. Too, the critical importance of academic English, especially for struggling learners, is an emphasis of *SVE*.

The lesson design for *SVE* is direct or guided instruction, since this structure has been found time and time again to be the most effective for all learners, and especially so for struggling learners. It is also critical in efforts to accelerate learning for any student. *SVE* also incorporates the research on the importance of time-on-task in improving learning and the efficacy of computer-assisted instruction.

Also, *SVE* includes the research-tested instructional strategies of multi-sensory processing, individualization, practice/repetition, fluency development, corrective feedback, and chunking/clustering. *SVE*'s spelling and vocabulary assessments have multiple potential uses in a data-driven school, including the importance of continuous progress monitoring.

Anticipated benefits of *SVE* implementation in an elementary school are as follows:

1. Lessons that develop science vocabulary will be helpful for all students, including ELLs, students with learning disabilities, and students who are economically disadvantaged—and the gifted/talented.

2. Mastery of vocabulary through *SVE* will improve student performance in the classroom and on state assessments.

3. Use of *SVE* with struggling learners will accelerate their learning and help narrow the achievement gap.

4. *SVE* requires little teacher involvement beyond lesson assignment, and the computer keeps track of student progress, thus saving teachers' time.

5. *SVE* is site-licensed, so a school may load it on as many computers at the campus as needed, making it very affordable and cost-effective.

6. *SVE* is grounded in scientific research in its content, lesson design, and instructional strategies.

7. *SVE* incorporates many features that motivate students to work hard and persevere.

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