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Common Core Science Standards: Implications for Students with Learning Disabilities

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The Common Core Science Standards represent a new effort to increase science learning for all students. These standards include a focus on English and language arts aspects of science learning, and three dimensions of science standards, including practices of science, crosscutting concepts of science, and disciplinary core ideas in the various subject areas. Many of these issues bring important implications for students with learning disabilities, which we discuss in turn. With appropriate supports and applications, students with learning disabilities can potentially benefit greatly from these new standards. However, the demands of these standards may require a higher level of support than those commonly available for many students with learning disabilities.

Throughout most of its history, American schools have been fiercely independent of federal control, and have made decisions about curriculum and other educational matters at the local level within guidelines that varied from state to state. Even at the local level, decisions about education are conducted in a highly political context (McCarthy, 2009). Remarkably, given the history of local control and state autonomy, the federal role in education has increased substantially from the Elementary and Secondary Education Act (ESA, 1965) through its reauthorization as the No Child Left Behind Act (NCLB, 2001). The increase in the federal role in education occurred despite President Clinton's declaration that the era of big government was over, and NCLB was signed into law by President George W. Bush, a member of the Republican party which has a long history of resisting increased federal involvement in education (McGuinn, 2006).

The current culture of high-stakes, standards-linked tests stemmed from concerns about the performance of American schools relative to images of historical efforts and the performance of students in other countries (Brigham, Berkeley, & Walker, 2012). Although the federal initiative to improve education through NCLB prompted the development of many test-linked standards designed to address this deficiency (Brigham, Tochterman, & Brigham, 2000), the ESA explicitly forbade the establishment of a national curriculum. Therefore, each state created standards and developed assessments to demonstrate accountability to the standards. However, the large number of resulting standards and tests that were developed and administered in schools made it difficult, if not impossible, to tell "whether Leslie in Louisiana was performing as well as or better than cousin Maddie in Michigan or whether either had attained the level of mathematics skills and knowledge of Kim who lived and attended school in Korea" (Feuer et al., 1999, p. 9). Reeves et al. (2011) suggested that the results of NCLB were limited, in part, because of the wide range of different standards and substantial variability among state assessments.

If uneven standards and non-comparable assessments were the stumbling blocks in the path of increasing the performance of American schools and the federal government could not impose a national curriculum, a voluntary coalition of states might develop a set of standards that could be implemented across the nation, or at least by a number of states who desired to participate in such an endeavor. In the spring of 2009, the National Governors Association and the Council of Chief State School Officers began work on the Common Core State Standards Initiative (Porter et al., 2012). Currently, 45 states and three territories have adopted the Common Core State Standards with at least a dozen actively making plans to implement the curricular changes (Common Core State Standards Initiative, 2012).

By 2010, the common core standards for English and Mathematics had been released. These standards contain recommendations for science literacy that are embedded within the English strand. The final common core standards for science remain in development, but some general outlines of the structure of the science standards are currently available. The English/Language Arts standards capture the essential nature of the Common Core State Standards as they differ from the current standards for education around the country. In the following sections, we summarize the major foci of the Common Core State Standards, describe the science elements embedded in the English/ Language Arts standards, and then finally turn to the proposed elements of the science standards themselves.

THE COMMON CORE

The common core provides for an increased focus on reading, writing, and other communication skills, and offers a

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general outline providing a reduced set of focal competencies. It is acknowledged that the common core is not the only content that can or should be taught in schools; however, participating schools ensure they will promote this content. Several assertions are provided regarding these standards. The Common Core State Standards Initiative (2012) reports that the standards:

(1) Are aligned with college and work expectations;
(2) Are clear, understandable and consistent;
(3) Include rigorous content and application of knowledge through high-order skills;
(4) Build upon strengths and lessons of current state standards;
(5) Are informed by other top performing countries, so that all students are prepared to succeed in our global economy and society; and
(6) Are evidence-based.

The Common Core State Standards Initiatives (2012b) also acknowledge applications of these standards to students with disabilities, and state that necessary supports and accommodations should be provided to facilitate access to the curriculum. These supports and accommodations include appropriate supports and related services, an Individualized Education Program aligned with grade level academic standards, and appropriately trained teachers and specialized support personnel to facilitate these supports and accommodations.

Science within English/Language Arts Standards

Within the English/Language Arts (ELA) Standards, every teacher is now considered to be a teacher of literacy skills (Reeves et al., 2011). Standards are developed separately for grades 6–8, grades 9–10, and grades 11–12; however, there is considerable overlap across grade levels in these standards. The standards themselves are presented in four categories: key ideas and details (e.g., citing textual evidence, main idea/summarization, and carrying out multistep scientific procedures); craft and structure (e.g., meaning of symbols and key terms, analyzing text structure and purpose); integration of knowledge and ideas (e.g., integration of text with graphic presentations); and range of reading and level of text complexity (comprehension of grade level science text complexity). Overall, they represent an aspiration toward high level science text comprehension skills for all students.

Mastery of complex vocabulary, higher-level text analysis, comprehension skills, and scientific writing are areas of relative weakness for many students. These areas are particularly problematic for students with learning disabilities (Lerner & Johns, 2012). Although acquisition of high level text comprehension skills is an important instructional objective, many students with learning disabilities are still learning important literacy skills even in the secondary grades, and may not be expected to learn best through independent study of science textbooks. We have argued previously that science knowledge and skills are better learned using other methods, particularly through hands-on, experiential learning activities (e.g., Brigham, Scruggs, & Mastropieri, 1992; Mastropieri et al., 1998; Scruggs & Mastropieri, 2007). This approach, additionally, has long been favored by professional science organizations (Bybee, 2010; Rutherford & Ahlgren, 1990).

Nevertheless, there is a need for at least some science content – particularly at the secondary grade levels – to be acquired via textbook, and learning to read and interpret literature regarding the sciences is a valuable skill. Therefore, some features of the ELA science standards may be helpful in focusing on literacy requirements. Significantly, these standards characterize English/language arts teachers as sharing responsibility for science learning, and science teachers as sharing responsibility for literacy acquisition (Strang, Lujan, & Barakos, 2011). This vision of shared responsibility allows for greater emphasis of literacy skills within the context of science learning, and highlights literacy as a key component of science learning, in an era in which literacy has been the increasing focus of educational reform. The outline of literacy skills provided by the ELA science standards provides a framework for teachers to consider as they develop objectives and lesson plans.

In addition, there is some evidence that students, including those with learning disabilities, can be trained to improve their expository text comprehension. Bakken, Mastropieri, and Scruggs (1997) taught secondary students with learning disabilities to identify different text structures (main idea, list, order) in science and other content passages, and to focus their study strategies on this structure. Students benefited substantially from this training, indicating that higher-level science text analysis can be taught, and students can benefit greatly from learning this skill. These and related skills such as providing guided notes (Konrad, Joseph, & Itoi, 2011) and teaching highlighting or note taking skills (Boyle & Weishaar, 2001) may significantly improve the opportunities for success in the inclusive science classroom. Mnemonic strategies can be employed to supplement text to facilitate vocabulary and concept learning from text (Mastropieri, Scruggs, & Levin, 1987; Scruggs & Mastropieri, 2000). In addition, successful writing strategies, such as the self-regulated strategy development (Harris, Graham, Mason, & Friedlander, 2008), could be employed to facilitate report writing.

Assistive technology has made text more accessible for students with learning disabilities. The Kurzweil 3000, for example (www.kurzweiledu.com), can provide significant support with text reading, study strategies, and report writing, for a variety of contexts relevant to science learning. The CAST Science Writer II (CAST, 2009) is intended to help middle and high school students draft, revise, and edit science reports. These and other technologies can provide considerable assistance with the ELA science standards.

In spite of available strategies and technologies, however, students with learning disabilities will likely find many aspects of the ELA standards challenging. For example, one grade 11–12 standard states, "Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible" (Common Core Standards Initiative, 2012c, p. 62). Meeting such standards in many cases will require substantial supports from English/language arts teachers, science teachers, special education teachers, as well as adapted materials and technologies, and it will be important to ensure that higher level supports are provided for all aspects of the higher standards.

The Science Standards

The science standards are said to be needed because the current approach fails to manifest systematic organization across multiple years of school, focuses on discrete facts that emphasize breadth over depth and fails to provide students with opportunities to experience how science is actually done (Committee on Conceptual Framework for the New K-12 Science Education Standards, 2012). These standards, as developed to date, will focus on three major dimensions: (a) scientific and engineering practices, (b) crosscutting concepts that unify the study of science and engineering through their common application across fields, and (c) core ideas in four disciplinary areas: physical sciences; life sciences; earth and space sciences; and engineering, technology, and applications of science (Committee on Conceptual Framework, 2012, p. 2). Engineering and technology are included with the natural sciences to reflect the importance of understanding the human-built world, and to recognize the value of better integrating the teaching and learning of science, engineering, and technology (Committee on Conceptual Framework, 2012, p. 2).

The science standards are to be the result of a two-step process. First, the development of a framework for science education by the National Research Council (completed); and second, the development of "next generation" science standards by Achieve, Inc. (in process but not yet completed).

Guiding Principles

The structure and content of the framework is based upon several guiding principles (Committee on Conceptual Framework, 2012, p. 24). Each of these principles has implications for students with learning disabilities, and is described separately.

1. ***The natural capacity of young children to learn science***. Children naturally develop a curiosity about the world around them and the way it works. This capacity should be encouraged at an early age, in a way developmentally appropriate to individual children. Just as teachers base skills instruction, such as reading or math, on the student's current level of functioning, it is important to base science instruction on the student's current level of understanding. For example, it has been seen that students with developmental disabilities may have scientific understandings similar to much younger children (Scruggs, Mastropieri, & Wolfe, 1995); this may also be true, to a lesser extent, for some students with learning disabilities. Mastropieri, Scruggs, and Butcher (1997) reported that students with learning disabilities were able to use inductive thinking to make relevant generalizations regarding pendulum movement. However, they were less likely to draw relevant inferences independently, more often requiring additional coaching and prompting than general education students. In any case, it is important that teachers consider current understandings of all students when planning science instruction.
2. ***A focus on core ideas over individual facts.*** Students with learning disabilities are unlikely to benefit from a curriculum that is a "mile wide and an inch deep," that encompasses a number of new vocabulary words and concepts to be learned for one unit with little relevance or overlap with the next unit. Such an approach focuses more on the relative weaknesses and less on the relative strengths of students with learning disabilities (Scruggs & Mastropieri, 1993). Mastropieri et al. (1998) reported that students with learning disabilities in an inclusive setting benefited from curriculum (with adaptations) that emphasized core ideas regarding ecosystems, and related experiential activities, over a textbook-based approach that focused on facts and vocabulary. Focus on "big ideas," that can be applied across individual subject domains has also been recommended (Coyne, Carnine, & Kameenui, 2011). Carnine (1989), for example, described the disjointed presentations of related topics provided in science textbooks, and concluded, that students with learning disabilities "need the support of a comprehensive intervention to succeed in demanding content area instruction" (p. 526). He explained how the principle of convection (the circular movement of a substance) can be used to explain phenomena observed in many different aspects of atmospheric and earth science. In chemistry, Carnine reported that students with learning disabilities and remedial students (who had not yet passed a high school science class) who were taught unifying concepts gained from 17.3 percent correct on the pretest to 76.9 percent correct on the posttest, approximating the performance of advanced placement students. Such emphasis of concepts across different subject areas may also address problems with generalization of knowledge often observed in students with learning disabilities (Mastropieri, Scruggs, & Butcher, 1997).
3. ***The development of true understanding over time***. Students' levels of understanding about important scientific concepts become increasingly sophisticated as they grow older; therefore, revisiting and developing conceptual understanding over time can be expected to promote a deep and thorough understanding of science. This is as true for students with learning disabilities as for any other students; in fact, redundancy in content presentation, within and across years of instruction, has been identified as an important component of effective instruction for students with disabilities (Mastropieri & Scruggs, in press).
4. ***The consideration both of knowledge and practice.*** We have long advocated the use of relevant activities to promote understanding of, and interest in,

scientific principles and concepts (e.g., Mastropieri & Scruggs, 1994). These activities promote the understanding of scientific method, and enforce the idea that science is based upon observation and discovery, and is not simply the sum of a series of facts. In a number of investigations, we have seen strong evidence that the introduction of practice in the form of relevant small group activities leads to increasing learning gains for students with learning disabilities (Mastropieri et al., 1998, 2006; Scruggs, Mastropieri, Bakken, & Brigham, 1993).

5. ***The linkage of science education to students' interests and experiences.*** To the greatest extent possible, science should reflect and build upon students' life experience and interests. Such linkages have been very helpful for students in content such as ecosystems (Mastropieri et al., 1998), simple machines (Scruggs & Mastropieri, 1994), and atmospheric science (Brigham et al., 1992). Activities using common, familiar materials can be very helpful in providing this linkage. Of course, given the comprehensive nature of science education, it is less realistic to assume that all subjects will be similarly interesting to all students. Nevertheless, teachers of all students should do what they can to enhance interest, and provide connections to life experiences (Brigham et al., 1992; Scruggs & Mastropieri, in press).
6. ***Promoting equity***. The promotion of equity is particularly appropriate in this context, especially as the principle emphasizes the importance of considering individual learning needs in planning and executing science instruction. The application of the principle of equity is of foundational importance to the field of special education in content areas as well as skills instruction.

The Three Dimensions of the Framework

The Framework for K-12 Science Education Standards consists of three "dimensions." These dimensions include (a) scientific and engineering practices, (b) crosscutting concepts, and (c) disciplinary core ideas. Each is discussed separately, with reference to the needs of students with learning disabilities.

Scientific and Engineering Practices

This dimension includes the methods of doing science and engineering, and includes such practices as planning and carrying out investigations, analyzing and interpreting data, discussing conclusions based on evidence, and constructing explanations. In this case, "practice" has supplanted "inquiry" because of the imprecise and multiple meanings of the latter term. It does encompass what was previously referred to as scientific "process" skills. We referred to some of these in earlier publications (e.g., Mastropieri et al., 1998; Scruggs & Mastropieri, 1994) as the "PORC" variables: predict, observe, record findings, and compare findings with predictions; they are used in scientific investigations to clarify thinking and focus attention on scientific method.

The study of scientific method extends across different subject areas in science, and helps to focus practices common to all science. As such, it is appropriately placed within its own "dimension"; these practices could be expected to be beneficial to other areas of science. Mastropieri et al. (2006) employed students working in pairs or small groups on activities of increasing difficulty level, to facilitate learning of a 12-week unit on the scientific method in middle school inclusive science classes. Included in the curriculum for the unit were activities involving charts and graphs, measurement, quantitative and qualitative research questions, independent and dependent variables, and experimental design. After training, all students (with and without disabilities) scored higher not only on the unit test, but also on the year-end statewide science test. These findings suggested that increased learning of scientific practices leads to increased understanding of other content areas.

Constructing explanations has also been a helpful practice for students with learning disabilities. Mastropieri, Scruggs, and colleagues implemented a series of investigations of the effects of student-constructed explanations of scientific facts (e.g., Scruggs, Mastropieri, & Sullivan, 1994; Sullivan, Mastropieri, & Scruggs, 1995). When students were actively "coached" through explanations for scientific facts (e.g., "why would it make sense that anteaters have long front claws?") they scored higher on tests then when they were directly provided with the same information. These experiments demonstrated that students with learning disabilities are able to reason scientifically, and to increase their learning when they do so.

An important component of scientific and engineering practices, which has received little research attention do date with respect to learning disabilities, includes engaging in arguments with evidence and constructing explanations and designing solutions. Some evidence from performance assessments suggests that students with learning disabilities can learn these practices, such as describing what the effects of acid rain might be on limestone statues (Scruggs et al., 1993), or what effects of soap might be on an ecosystem (Scruggs et al., 1993). This notion could be expanded to include verbal discourse, such as debating science or engineering issues. For an example from social studies, MacArthur, Ferretti, and Okolo (2002) taught students with learning disabilities along with their peers in inclusive classes to investigate the experiences of one of two immigrant groups to the United States. Students used a variety of sources to form their arguments including planning sheets that contained reasons and evidence from both immigrant and nativist positions prior to debating. Findings revealed that all students generally gained in knowledge about the issues surrounding immigration, and provide implications for developing argument in science and engineering.

Crosscutting Concepts

The crosscutting concepts are broad themes that have relevance across the content areas of science included in the

3rd dimension of the common core science standards. These concepts are similar to the themes proposed by different science organizations over the past years, and signal that science should be understood more broadly than just as a number of separate, individual subject domains, with little relation to each other. These concepts include:

(1) patterns;
(2) cause and effect;
(3) scale, proportion, and quantity;
(4) systems and system models;
(5) energy and matter: flows, cycles, and conservation;
(6) structure and function; and
(7) stability and change.

For example, scale, proportion, and quantity can be demonstrated to be important considerations in the study of plant growth and development, as well as pendulum movement, and chemical reactions. Each of these concepts—previously referred to by science organizations as unifying concepts or common themes—can be an important part of virtually all areas of science, and also has applications in engineered systems. Again, concepts that can be demonstrated across different areas of science can strengthen understandings and promote generalized learning.

Disciplinary Core Ideas

The third dimension of the framework focuses upon the substantive core content of science disciplines of physical science, life science, earth and space science, and engineering. The planning committee determined to focus on foundational core knowledge upon which future knowledge could be built:

> But given the cornucopia of information available today virtually at a touch— people live, after all, in an information age—an important role of science education is not to teach "all the facts" but rather to prepare students with sufficient core knowledge so that they can later acquire additional information on their own. An education focused on a limited set of ideas and practices in science and engineering should enable students to evaluate and select reliable sources of scientific information and allow them to continue their development well beyond their K-12 school years as science learners, users of scientific knowledge, and perhaps also as producers of such knowledge. (Committee on Conceptual Framework, 2012, p. 31)

For example, under physical science, the committee included as core ideas (a) matter and its interactions, (b) motion and stability: forces and interactions, (c) energy, and (d) waves and their applications in technologies for information transfer (Committee on Conceptual Framework, 2012 p. 3). These core ideas are intended to unify a number of subordinate facts and concepts, and provide a framework for development of learning, throughout the school grades and throughout life.

Overall, the common core framework contains much that appears appropriate for students with learning disabilities. Certainly, the ideas of integrating content across thematic domains, focusing on a smaller number of basic core concepts, and considering practices as well as content of science, all appear to be relatively compatible with the observed needs of students with learning disabilities. Of particular benefit is an explicit consideration of the English/language arts aspects of science learning, and the responsibility of English as well as science teachers to address these relevant aspects of learning.

Presently employed state standards often have been dominated by factual recall. Common core standards are more explicitly oriented toward using and applying scientific knowledge. Application of knowledge requires the union of science content knowledge, conceptual thinking, and linguistic skills to organize and represent the information. Although these standards are focused upon greater depth of knowledge, successful performance suggests the necessary presence of all the elements; a breakdown at any point could lead to unsuccessful overall performance.

Presently, scope and sequence guides for science instruction are less likely either to recognize or to integrate learning across the various disciplines; nor is teacher training generally aligned with cross-disciplinary standards. These practices will need to change as the common core standards are implemented.

The new standards call for revised tests to be made available by 2014. This is a very rapid implementation period. However, a number of test developers speculate that the timeline is too short for meaningful development of assessments that adequately capture the emphasis on communication in the new standards (Sparks, 2011). It is thus unclear how progress toward mastery of the Common Core State Standards will be measured.

These new standards also provide implications for teacher evaluation. Current reform initiatives call for basing teacher pay, in part, upon student performance (Gratz, 2009). How will such evaluation practices be implemented with complex skills that necessarily require the deliberate contributions of several teachers over several years? That is, if learning failure occurs in part because students were not effectively taught important foundational concepts at earlier grade levels, should the present teacher be faulted for this?

Another issue to consider is the fact that the common core standards implicitly assume that students will benefit from multiple representations in science, and that it will clarify and enhance their learning. Although this idea has intuitive appeal, the reality may be more complex. Kozma reviewed experimental and naturalistic research comparing the understandings of chemists and chemistry students. He concluded,

> Experts are able to make connections across multiple representations and coordinate the features of these representations to support their discourse about the entities and processes that underlie them all. In our experimental study, students were not able to make these connections. (Kozma, 2003, p. 9)

Tai, Loher, and Brigham (2006) also noted that science educators often lacked substantial domain expertise across different subdisciplines (i.e., biology, physics, and chemistry). Implementation of the common core standards will also have to consider the actual learning consequences, and needed adaptations, as these standards are applied in schools.

STUDENTS WITH DISABILITIES AND THE STANDARDS

The Common Core standards (Committee on Conceptual Framework, 2012) contain three explicit references to students with disabilities:

(1) "Diversity should be made visible in the new standards in ways that might, for example, involve. . . ensuring that students with particular learning disabilities are not excluded from appropriate science learning." (p. 308)
(2) ". . .it is not clear whether these [learning] theories apply equally well to diverse populations of students, including those who have been poorly served in the science and engineering education system—females, underrepresented minorities, English language learners, and students with disabilities. These kinds of natural variations among individuals need to be better understood through empirical study and incorporated into the cognitive models of learning that serve as a basis for assessment design." (pp. 317–318)
(3) "How can assessments be developed that are fair, both for different demographic groups and for students with disabilities? Have examples of these kinds of assessments for the practices, concepts, and core ideas in the framework been developed and implemented" (p. 339)?

These statements demonstrate an awareness of important issues in education of individuals with disabilities, including standards, instructional practice, and assessments, and for the necessity for special efforts to meet the needs of diverse populations, including students with disabilities. These statements also provide a significant advance from previous positions of science organizations that made little acknowledgement of the need for differentiated instructional practice for students with disabilities (e.g., Rutherford & Ahlgren, 1990). Unfortunately, there is little in the standards that provide any insights on how these will be realized. Further—although this not stated explicitly—an implicit assumption seems to be that, with the application of some specific considerations, all students with disabilities can be taught successfully in the general education science class. Although this is a worthy goal to which we should rightly aspire, we should not fail to consider alternative means for teaching science for students who continue to struggle in general education classes. Finally, we should acknowledge the levels of support required to promote mastery within these standards. The standards are designed to increase the rigor for *all* students, but require substantially increased performance in areas that are considered particularly problematic for individuals with learning disabilities. Therefore, the Common Core Science Standards are likely to require increased supports from special and general educators beyond those already in place for students with disabilities.

IMPLICATIONS FOR INSTRUCTION

Research over the past few decades has provided important information on implications for science instruction for students with learning disabilities. Most of this information is relevant to implementation of the common core standards, which provides positive implications as well as challenges (see also the special issue of *Learning Disabilities Research and Practice,* 2011, vol. 26, no. 4, on science education and learning disabilities).

Students with learning disabilities can benefit greatly from experiential learning, in a variety of contexts, particularly when adapted appropriately. When science learning is mediated through hands-on, small-group activities, experimentation, class discussion, adapted practice activities (such as worksheets and reports) and review, there is little reason not to believe that students with learning disabilities can benefit greatly, in many cases approaching the level of learning of general education students (Bay, Staver, & Bryan, 1990; Mastropieri et al., 1998; Scruggs et al., 1993). This is because such approaches to learning interact with the strengths of many students with learning disabilities (e.g., learning through experience and concrete examples) and de-emphasizes relative weaknesses (e.g., independent study from text; see Scruggs & Mastropieri, 2007). Even when students are provided with such learning environments, however, research suggests that additional guidance and structure will be necessary for them to comprehend fully and draw relevant inferences (Mastropieri, Scruggs, Boon, & Carter, 2001; Mastropieri et al., 1997).

Although learning-by-doing can be a very effective approach to science learning, it seems unlikely that all relevant science curriculum can be covered in this way, particularly at the secondary level, where the need for study from complex textbooks is commonly required. This emphasis on studying independently from text places a particular burden on many students with learning disabilities, for whom text processing represents a relative weakness. Research has identified a number of strategies that have been seen to be of help in this regard. Effective strategies include reading comprehension strategies, including text structure analysis (e.g., Bakken et al., 1997; Mason & Hedlin, 2011); training in highlighting, outlining, and note taking (Boyle Weishaar, 2001); guided notes (Konrad et al., 2011); mnemonic strategies for scientific vocabulary concepts (Brigham et al., 2011); graphic organizers to enhance comprehension and promote connections (Dexter, Park, & Hughes, 2011); and content learning enhancement, through direct instruction (McCleery & Tindal, 1999), small group activities (Mastropieri et al., 2006) and peer tutoring (Maheady & Gard, 2010). These strategies, overall, have produced substantial effect sizes (Scruggs, Mastropieri, Berkeley, & Graetz, 2010), and may be very useful in implementing the Common Core Science Standards.

Unfortunately, under even the best circumstances, students will need to be able to read text accurately and fluently, and many students with learning disabilities may experience great difficulties in this regard. Advances in technology such as the Kurzweil 3000 and other text-to-speech devices can be very helpful, as can the CAST Science Writer II for report writing. However, students who, by the secondary grade levels, have not acquired appropriate literacy skills will probably experience substantial difficulties with secondary science content. Recent research has underlined the persistent nature of reading difficulties, and suggests that even with extensive additional targeted instruction, dramatic short-term gains in overall reading skill are not easily accomplished with students with a history of significant reading problems (e.g., Vaughn et al., 2010). With the collaboration and cooperation of the English/language arts teachers, this problem may be ameliorated somewhat.

Although success in inclusive science classes has often been realized (e.g., Mastropieri, Scruggs, & Graetz, 2005; Mastropieri et al., 2006), there is no assurance that this will prove to be true of all students with disabilities, including all students with learning disabilities, many of whom have already failed to learn successfully in these environments. Although students with learning disabilities are clearly able to learn science, whether all students with learning disabilities can learn effectively in general education science environments, at the same intensity, rate, and pace of content coverage, remains to be demonstrated. Unfortunately, special education teachers may not have the necessary skills in science education in many cases, and even with intensive special education, there is no assurance that students with learning disabilities will be able to master core content at the same pace as their general education peers.

Another significant issue for inclusive science instruction concerns the ability or willingness of general education teachers to implement specialized or differentiated instruction. Results from observational studies and attitude surveys in this regard are not entirely positive. Scruggs and Mastropieri (1996) and Scruggs, Mastropieri, and Leins (2012) reviewed all available survey research of teacher attitudes toward inclusion, and reported that, although a majority supported inclusive practices, only a small minority agreed they had sufficient time, training, or support to implement inclusion effectively. In a recent synthesis of all available qualitative research on co-teaching, Scruggs, Mastropieri, and McDuffie (2007) concluded that special education co-teachers served mostly in a supporting capacity, and rarely employed specialized instructional strategies to assist students with disabilities. These findings suggest that much work remains to be done to design and implement effective science instruction in inclusive environments.

Conclusion

Common Core Science Standards (the final version of which is yet to be released) contain much of importance to the education of students with learning disabilities. The integration of knowledge, the focus on necessary literacy requirements, the emphasis on experience and understanding, and the focus on fundamental core concepts throughout subject areas and grade levels, can all be expected to be beneficial to students with learning disabilities. We believe that the increased focus on content area knowledge will also prove to be helpful in this endeavor. Previous science research identified circumstances in which students with learning disabilities benefited greatly from adaptations such as mnemonic strategies, text processing strategies, adapted activities, peer mediation, and explicit questioning strategies. The great challenge for the future will be to identify means for implementing these strategies and supports on a broad scale, and monitoring their impact, in a variety of settings. In this way, students with learning disabilities can anticipate much greater success in science learning.

REFERENCES

Bakken, J. P., Mastropieri, M. A., & Scruggs, T. E. (1997). Reading comprehension of expository science material and students with learning disabilities: A comparison of strategies. *Journal of Special Education*, *31*, 300–324. doi:10.1177/002246699703100302

Bay, M., Staver, J. R., Bryan, T., & Hale, J. B. (1992). Science instruction for the mildly handicapped: Direct instruction versus discovery teaching. *Journal of Research in Science Teaching*, *29*, 555–570. doi:10.1002/tea.3660290605

Boyle, J. R., & Weishaar, M. (2001). The effects of strategic note taking on the recall and comprehension of lecture information for high school students with learning disabilities. *Learning Disabilities Research and Practice*, *16*, 133–141. doi:10.1111/0938-8982.00014

Brigham, F. J., Berkeley, S., & Walker, E. (2012). Navigating the measurement and monitoring maze. *Exceptionality*, *20*, 133–142. doi: 10.1080/09362835.2012.669298

Brigham, F. J., Scruggs, T. E., & Mastropieri, M. A. (1992). The effect of teacher enthusiasm on the learning and behavior of learning disabled students. *Learning Disabilities Research and Practice*, *7*, 68–73.

Brigham, F. J., Scruggs, T. E., & Mastropieri, M. A. (2011). Science and students with learning disabilities. *Learning Disabilities Research and Practice*, *26*, 223–232. doi: 10.1111/j.1540-5826.2011.00343.x

Brigham, F. J., Tochterman, S., & Brigham, M. S. P. (2000). Students with emotional and behavioral disorders and their teachers in test-linked systems of accountability. *Assessment for Effective Intervention*, *26*(1), 19–27.

Bybee, R. (2010). The teaching of science: 21st-century perspectives. Arlington, VA: NSTA Press.

Carnine, D. (1989). Teaching complex content to learning disabled students: The role of technology. *Exceptional Children*, *55*, 524–533.

CAST (2009). *CAST Science Writer II*. Cambridge, MA: Author.

Committee on Conceptual Framework for the New K-12 Science Education Standards (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

Common Core State Standards Initiative. (2012). *Adoption by state*. Retrieved June 20, 2012, from http://www.cor

Dexter, D. D., Park, Y. J., & Hughes, C. A. (2011). A meta-analytic review of graphic organizers and science instruction for adolescents with learning disabilities: Implications for the intermediate and secondary science classroom. *Learning Disabilities Research and Practice*, *26*, 204–213. doi: 10.1111/j.1540-5826.2011.00341.x

The Elementary and Secondary Education Act (ESEA), 89–10 C.F.R. § 20 U.S.C. 7305 et seq (1965).

Feuer, M. J., Holland, P. W., Green, B. F., Bertenthal, M. W., Hemphil, F. C., & National Research Council Committee on Equivalency and Linkage of Educational Tests. (Eds.). (1999). *Uncommon measures: Equivalence and linkage among educational tests*. Washington, DC: National Academy Press.

Gratz, G. B., (2009). *The peril and promise of performance pay: making education compensation work*. Lanham, MD: Rowman & Littlefield.

Harris, K, Graham, S, Mason, L. & Friedlander, B. (2008). Powerful writing strategies for all students. Baltimore, MD: Brookes.

Konrad, M., Joseph, L. M., & Itoi, M. (2011). Using guided notes to enhance instruction for all students. *Intervention in School and Clinic*, *46*, 131–140. doi: 10.1177/1053451210378163

Kozma, R. (2003). Material and social affordances of multiple representations for science understanding. *Learning and Instruction*, *13*, 205–226. doi: 10.1016/S0959-4752(02)00021-X

Lerner, J. W., & Johns, B. H. (2012). *Learning disabilities and related mild disabilities*. Belmont, CA: Wadsworth.

MacArthur, A. C., Ferretti, R. P., & Okolo, C. M. (2002). On defending controversial viewpoints: Debates of sixth-graders about the desirability of early 20th-century American immigration. *Learning Disabilities Research & Practice*, *17*, 160–172.

Maheady, L., & Gard, J. (2010). Classwide peer tutoring: Practice, theory, and a personal narrative. *Intervention in School and Clinic*, *46*, 71–78. doi: 10.1177/1053451210376359

Mason, L. H., & Hedlin, L. R. (2011). Reading science text: Challenges for students with learning disabilities and considerations for teachers. *Learning Disabilities Research and Practice*, *26*, 211–222. doi: 10.1111/j.1540-5826.2011.00342.x

Mastropieri, M. A., & Scruggs, T. E. (1994). Text-based vs. activities-oriented science curriculum: Implications for students with disabilities. *Remedial and Special Education*, *15*, 72–85. doi: 10.1177/074193259401500203

Mastropieri, M. A., & Scruggs, T. E. (in press). *The inclusive classroom: Strategies for effective differentiated instruction* (5th ed.). Underwood Cliffs, NJ: Prentice Hall.

Mastropieri, M. A., Scruggs, T. E., Boon, R., & Carter, K. B. (2001). Correlates of inquiry learning in science: Constructing concepts of density and buoyancy. *Remedial and Special Education*, *22*, 130–138. doi: 10.1177/074193250102200301

Mastropieri, M. A., Scruggs, T. E., & Butcher, K. (1997). How effective is inquiry learning for students with mild disabilities? *Journal of Special Education*, *31*, 199–211. doi: 10.1177/002246699703100203

Mastropieri, M. A., Scruggs, T. E., & Graetz, J. (2005). Cognition and learning in inclusive high school chemistry classes. In T. E. Scruggs & M. A. Mastropieri (Eds.), *Cognition and learning in diverse settings: Advances in learning and behavioral disabilities* (vol. *18*, pp. 107–118). Oxford, UK: Elsevier.

Mastropieri, M. A., Scruggs, T. E., & Levin, J. R. (1987). Learning disabled students' memory for expository prose: Mnemonic vs. nonmnemonic pictures. *American Educational Research Journal*, *24*, 505–519. doi: 10.3102/00028312024004505

Mastropieri, M. A., Scruggs, T. E., Mantzicopoulos, P. Y., Sturgeon, A., Goodwin, L., & Chung, S. (1998). "A place where living things affect and depend on each other": Qualitative and quantitative outcomes associated with inclusive science teaching. *Science Education*, *82*, 163–179. doi: 10.1002/(SICI)1098–237X(199804)82:23.0.CO;2-C

Mastropieri, M. A., Scruggs, T. E., Norland, J., Berkeley, S., McDuffie, K., Tornquist, E. H., et al. (2006). Differentiated curriculum enhancement in inclusive middle school science: Effects on classroom and high-stakes tests. *Journal of Special Education*, *40*, 130–137. doi: 10.1177/00224669060400030101

McCarthy, M. (2009). Research on actors and institutions involved in education policy. In G. Sykes, B. L. Schneider, D. N. Plank & T. G. Ford (Eds.), *Handbook of education policy research* (pp. 842–847). New York, Washington, DC: Routledge, American Educational Research Association.

McCleery, J. A., & Tindal, G. A. (1999). Teaching the scientific method to at-risk students and students with learning disabilities through concept anchoring and explicit instruction. *Remedial and Special Education*, *20*, 7–18. doi: 10.1177/074193259902000102

McGuinn, P. J. (2006). *No Child Left Behind and the transformation of federal education policy*. *1965–2005*. Lawrence, KS: University Press of Kansas.

Mervis, J. (2007). A new twist on training teachers. *Science*, *316*(5829), 1270–1277. doi: 10.1126/science.316.5829.1270

Porter, W., Riley, R., Towne, L., Hightower, A. M., Lloyd, S. C., Sellers, K. L., et al. (2012). *Preparing for change: A national perspective on Common Core State Standards imple-mentation planning*. Seattle, WA: Education First, & Bethesda, MD, Editorial Projects in Education.

Reeves, D. B., Wiggs, M. D., Lassiter, C. J., Piercy, T. D., Ventura, S., & Bell, B. (2011). *Navigating implementation of the common core state standards*. Englewood, CO: Lead +Learn Press.

Rutherford, F. J., & Alghren, A. (1990). *Science for all Americans*. New York: Oxford University Press.

Scruggs, T. E., & Mastropieri, M. A. (1994). The construction of scientific knowledge by students with mild disabilities. *Journal of Special Education*, *28*, 307–321. doi: 10.1177/002246699402800306

Scruggs, T. E., & Mastropieri, M. A. (1996). Teacher perceptions of mainstreaming/ inclusion, 1958–1995: A research synthesis. *Exceptional Children*, *63*, 59–74.

Scruggs, T. E., & Mastropieri, M. A. (2000). The effectiveness of mnemonic instruction for students with learning and behavior problems: An update and research synthesis. *Journal of Behavioral Education*, *10*, 163–173. doi: 10.1023/A:1016640214368

Scruggs, T. E., & Mastropieri, M. A. (2007). Science learning in special education: The case for constructed vs. instructed learning. *Exceptionality*, *15*, 57–74. doi: 10.1080/09362830701294144

Scruggs, T. E., & Mastropieri, M. A. (in press). Science and social studies. In H. L. Swanson, K. Harris, & S. Graham (Eds.), *Handbook of learning disabilities* (2nd ed.). New York: Guilford.

Scruggs, T. E., Mastropieri, M. A., Bakken, J. P., & Brigham, F. J. (1993). Reading vs. doing: The relative effectiveness of textbook-based and inquiry-oriented approaches to science education. *Journal of Special Education*, *27*, 1–15. doi: 10.1177/002246699302700101

Scruggs, T. E., Mastropieri, M. A., Berkeley, S., & Graetz, J. (2010). Do special education interventions increase the learning of secondary content? A meta-analysis. *Remedial and Special Education*, *31*, 437–449. doi:10.1177/0741932508327465

Scruggs, T. E., Mastropieri, M. A., & Leins, P. (2012). *Teacher attitudes toward inclusion: Are they changing?* Fairfax, VA: George Mason University, Division of Special Education and Disability Research.

Scruggs, T. E., Mastropieri, M. A., & Sullivan, G. S. (1994). Promoting relational thinking skills: Elaborative interrogation for mildly handicapped students. *Exceptional Children*, *60*, 450–457.

Scruggs, T. E., Mastropieri, M. A., & Wolfe, S. (1995). Scientific reasoning of students with mental retardation: Investigating preconceptions and conceptual change. *Exceptionality*, *5*, 223–244. doi: 10.1002/sce.3730790303

Sparks, S. D. (2011). Experts see hurdles ahead for Common Core tests. *Education Week*, *30*(28), 11.

Strang, C., Lujan, V., & Barakos, L. (2011, September). *Exploring the new NRC Framework for K-12 Science Education*. Berkeley, CA.: Center for Instruction webinar, Lawrence Hall of Science Retrieved July 20, 2012, from http://www.centeroninstruction.org/files/NRC%20Framework%2Epptx

Sullivan, G. S., Mastropieri, M. A., & Scruggs, T. E. (1995). Reasoning and remembering: Coaching thinking with students with learning disabilities. *Journal of Special Education*, *29*, 310–322. doi: 10.1177/002246699502900304

Tai, R. H., Loehr, J. F., & Brigham, F. J. (2006). An exploration of the use of eye-gaze tracking to study problem-solving on standardized science assessments. *International Journal of Research & Method in Education*, *29*, 185–208. doi: 10.1080/17437270600891614

Vaughn, S., Cirino, P. T., Wanzek, J., Wexler, J., Fletcher, J. M., Denton, C. D., et al. (2010). Response to intervention for middle school students with reading difficulties: Effects of a primary and secondary intervention. *School Psychology Review*, *39*, 3–21.

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