CITEd Center for Implementing Technology in Education

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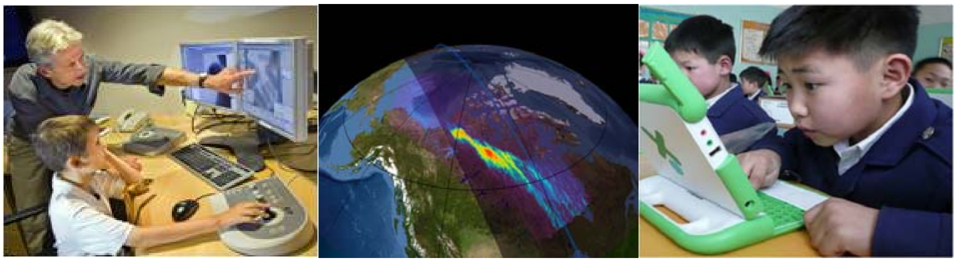
Using Technology to Support Struggling Students in Science



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About the Center for Implementing Technology in Education
The Center for Implementing Technology in Education (CITEd), established in 2005, advances learning opportunities for *all* students, with a special focus on students with disabilities. CITEd supports leadership at state and local education agencies to integrate instructional technology for all students to achieve high educational standards. The Center provides this support through identification of best practices, innovative online technical assistance tools, professional development, and communities of practice. CITEd is funded by the U.S. Department of Education, Office of Special Education Programs and is a cooperative effort of the American Institutes for Research (AIR), the Center for Applied Special Technology (CAST), and the Education Development Center (EDC). The contents of this brief were developed under a grant (Cooperative Agreement #H327M040004) from the U.S. Department of Education. However, these contents do not necessarily represent the policy of the U.S. Department of Education, and you should not assume endorsement by the federal government.

CONTENTS

SCIENCE EDUCATION FOR ALL STUDENTS

In an increasingly complex world, all students need to be scientifically literate. For some students, science and other advanced careers match their interests and abilities. For all students, however, basic literacy in science concepts and processes is critical. All students need to understand what it means to think like a scientist and how to evaluate information that is called “scientific.” In addition, many careers during the 21st century will call for not only particular subject knowledge but also the ability to collaborate and solve problems using science, technology, engineering, and mathematics (STEM) skills. Struggling students are no exception. They need the same types of knowledge and skills, and they often require additional supports to be successful. The success of all students in these areas is a major priority of the U.S. Department of Education.

Science is a critical element of STEM education. STEM learning research suggests that the most meaningful learning occurs when students are engaged in authentic activities that ask them to behave like chemists, computer programmers, mathematicians, engineers, or archeologists—that is, when they engage in activities that reflect the way professionals use and create knowledge in real-life contexts (Herrington & Kervin, 2007; Tan, Yeo, & Lim, 2005). Yet in these activities, struggling students, including those with disabilities, face new challenges. Many of these activities use technology in authentic workplace ways and on platforms, devices, and applications that may not be accessible to all students.

This report discusses how struggling students can be supported in science education and how accessible and assistive technologies can help. Following a background introduction to the topic and challenges, the report is organized into five sections, each addressing an important dimension of K–12 science education within the context of 21st century skills. Each section presents research findings and strategies to guide educators in implementing science education that is *inclusive*. Throughout, the reader is referred to research and technologies (software and devices) included in www.TechMatrix.org, an online database of technologies reviewed for assistive and accessibility features maintained by the National Center for Technology Innovation (NCTI).

Background

This report addresses a variety of complex issues, including a diverse population of learners and a curricular area that varies across localities and grades. Further, it focuses on the impact of federal policies that are aiming for universal access and outcomes for all students and on a research base that is still evolving.

Who Are Struggling Students?

Struggling students are those for whom traditional educational practices do not meet their needs and abilities. In this broad category are students with historical disadvantages and others diagnosed with conditions that may impair their ability to access or benefit from educational opportunities. Some struggling students have cognitive or physical impairments. However, not all students with physical disabilities are struggling students. One common definition is that struggling students are two or more years behind grade-level expectations (National Longitudinal Transition Study-2, 2003).

Struggling students are often identified by different categories: language, ability level, special education placement, socio-economic status, gender. In many cases, there is substantial overlap among categories. For this report, we include in our definition of struggling students their level of engagement and achievement in school, particularly in science.

Students with disabilities are covered under laws and regulations designed to guarantee their full participation in education. These laws require that students be educated in the least restrictive environment possible, that they be taught with the general curriculum to the greatest extent, and that instructional materials be available in accessible formats based on their needs. In many cases, these students have individual education programs (IEPs), which are formal plans that coordinate the work of teachers and specialists to meet students' individual educational needs (Individuals with Disabilities Education Act Amendments of 1997, 2004).

The focus of these overlapping regulations is to include students with disabilities in mainstream educational processes where they have access to the same instructional and social resources as other students (Heumann, 1999; Mastropieri & Scruggs, 2000; Wade & Zone, 2000). The goal is to offer an inclusive education that supports students in the general classroom and curriculum. One way to meet that goal is the effective use of technology and accessible instructional materials to teach the general curriculum. Other important factors are the beliefs and attitudes of the teachers and special educators who are responsible for the students (McGinnis, 2006).

Inclusion is not an all-or-nothing proposition, but rather can occur in different degrees. It is important to note that of the approximately 6 million children in special education, over 95 % spend some of their day in mainstream classrooms, with almost 60% in mainstream classrooms 80% of their day (Gray, Silver-Pacuilla, Overton, & Brann, 2010).

The Knowledge Base on Struggling Students, Science, and Technology

The knowledge base is meager on the engagement and learning of science by struggling students, including those with disabilities, (Mastropieri & Scruggs, 1994). Many of the recommendations in this literature focus on students' ability to manipulate texts. These recommendations include focusing on language, including reading (Mastropieri, Scruggs, & Graetz, 2004), and on mnemonic instruction of science concepts (Scruggs & Mastropieri, 1991).

McGinnis and Stefanich (2007) recommend a research agenda focused on a spectrum of practice dimensions, such as how teachers include students with special needs in science classrooms, the role of disaggregated data that can identify their performance, professional development opportunities to address teacher sensitivity and understanding, and the role of outcomes and assessment processes. They also highlight the need to understand school culture issues and collaboration models between general education and special education teachers for science.

An important gap in the knowledge base is the area of technology to support struggling students in science. Science education often involves technology, and rich but distinct literatures on technology and student learning of science do exist, but discussions of accessibility for students with disabilities are rare. Research that does focus on students with disabilities often has two related weaknesses. The first is that the approach to science is often based on a traditional perspective that emphasizes content knowledge, rather than on the more integrated approach that is oriented toward process. The second is that this research tends to be more descriptive and less rigorous as a result of the often small numbers of struggling students in specific educational settings. Further, much of this research is reported in journals dedicated to special populations, not in mainstream publications where it is likely to be more widely read.

Current Trends in Science Education

Science education can be thought of in many ways. Two predominant views are that it is (1) about facts or science content (a cognitive approach) and (2) about the practices of doing science or about science process (a process approach). Over the last century, the pendulum has swung many times between more cognitive- and more process-oriented views of science (DeBoer, 1991). Many different theoretical influences have affected science education, including behaviorist, developmental, cognitive, and sociocultural perspectives, each viewing learning in different ways (McGinnis, 2006).

Science education also entails considerable variation as a curricular area. For example, it covers many subfields, from physics to biology to earth science. It progresses in complexity as students advance. For example, the focus on human scale and experience in the younger grades progresses to modeling and then to a broader range of processes in middle grades, followed by more formal and mathematical approaches in late secondary school (Mohan, Sharma, Cho, Jin, & Anderson, 2006).

The current focus on 21st century skills brings school science closer to a model that offers a real window into the practical application of science where scientists and others routinely use a number of technology tools in their daily practice. These tools include virtual environments and simulations; models of scientific phenomena; and collaborative tools such as email, video conferencing, and shared workspaces like wikis. In professional life, scientists increasingly focus on analyses that are based on databases built by other scientists (Bowker, 2006). They develop models of the world that they share and critique, sometimes across great distances. Similarly, engineers, applied mathematicians, and technologists/computer scientists do more than design. They work with clients to understand goals and constraints. They work within budgets and timelines. They develop designs with specific materials and design constraints, and they often work in an iterative modeling process that is similar to the process used by scientists in what have been called *design sciences* (Simon, 1996).

Technology plays an important role in learning 21st century science. For students with disabilities, assistive technology provides access to materials and learning. Technology provides a means of engagement and participation in state-of-the-art learning (Collins & Halverson, 2009). For all students in science education, technology is an important way of representing authentic practice where groups of individuals use technology to jointly identify and solve problems (Hutchins, 1996).

FIVE DIMENSIONS OF SCIENCE EDUCATION FOR ALL STUDENTS

To consider some of the important dimensions of science education for struggling students and how technology may help, this report highlights five key dimensions:

1. Physically doing science or “getting a mechanic grip” on the natural world
2. Visualization, representation, and modeling
3. Science literacy, vocabulary, and discourse
4. Questions, argumentation, and use of evidence
5. Student engagement and identity with science

Not all of these dimensions affect all students in the same ways. This report discusses, for each dimension, which approach and technology resources may be available to help make science education more inclusive.

Physically Doing Science or “Getting a Mechanic Grip” on the Natural World

An important aspect of both traditional and newer approaches to science education involves doing physical tasks, such as taking soil samples, mixing chemicals, using Bunsen burners, and performing dissections. Although the work that occurs in conjunction with textbooks and lab books is important in establishing a conceptual foundation, for many teachers and students alike, science is a subject that involves physical work.

Across the range of scientific disciplines, students do important physical and tangible work as they make abstract concepts more concrete (Mancuso & Hunter, 1985; Piaget, 1983) and record data about natural states and processes. Researchers Lehrer, Shauble, and Petrosino (2001) use the term “mechanic grip” to refer to the physical act of performing science during which students contact the natural world. This type of physical work presents barriers if students have a disability that impairs their ability to perform certain physical tasks.

Educational technologies can help students get a mechanic grip by providing alternative experiences for building science proficiency and knowledge. These technologies, in addition to offering substitutes for the natural world, allow other types of interactions that have advantages over the natural world because they allow students to visualize and virtually interact with phenomena in ways not directly possible because the natural processes are too fast, small, slow, or large to be easily perceived by people.

Educational technology can make a difference in three areas:

- Virtual experiments and activities
- Simulations of the natural world
- Observation and measurement supports, including probes and virtual world data collection functions

Virtual Experiments and Activities

When—because of cost, time, safety issues, or accessibility—students are unable to engage in certain science class activities, virtual experiments and dissections can be effective alternatives (Huppert, Lomask, & Lazarowitz, 2002; Robertson, Johnston, & Nip, 1995). These types of activities give students opportunities to see a representation of real “bench science” and to manipulate it with virtual tools.

Simulations of the Natural World

Virtual worlds involve using computers to display a setting and allow simulation participants to work and interact with it. One of the more advanced of these virtual worlds is EcoMUVE (Dede, 2009), which is being developed by researchers at Harvard University (http://www.ecomuve.org/). MUVE stands for Multiple User Virtual Environment. It allows groups of students to work in the environment at the same time: making observations, taking samples, and communicating with one another.

Virtual Instrumentation/Data Collection

Technology now enables a wide range of devices to connect to the Internet so that science activities can be conducted virtually and over great distances. A recent project by researchers at Northwestern University and the Massachusetts Institute of Technology called iLabs (http://www.ilabcentral.org/) does just that by connecting scientific equipment to the Internet so that students can interact with the equipment remotely. In addition to providing remote access and an accessible experience, this technology gives students experiences with equipment that is often too expensive or dangerous for the classroom (Hardison, DeLong, Bailey, & Harward, 2006; Huppert et al., 2002).

Implications for Educators

To accommodate students who have physical barriers to performing standard science education tasks, teachers can take the following measures to ensure that those students have the best opportunity to get a conceptual grip on nature and natural processes:

- Explore using technology, including classroom projection/interactive whiteboard technology, to support student visualization and modeling.
- Arrange teams so that students with disabilities are paired with other students who can support them and perform some tasks that they otherwise could not do.
- Distribute the team workload so that students with disabilities take on a share of the team responsibility that matches their maximum/target ability to contribute.
- Search the www.TechMatrix.org for tools that support science education and have the characteristics described above.

Visualization, Representation, and Modeling

Doing science often involves creating abstract representations and using specialized visual genres (Lynch & Woolgar, 1990), but it includes more than images (Lemke, 2002). It involves specialized types of representations to describe processes that occur at speeds and scales that are not easily observable by the naked eye.

For example, chemistry texts often use images that represent atoms and molecules with different colors for different types of nanoscopic entities. In reality, these nano-entities such as molecules and electrons do not have color and are not stationary. These entities and the changes in them (e.g., reactions) occur at a very small scale and are difficult to observe. Similarly, in ecology, natural cycles such as the carbon cycle and food webs occur over long time scales and are equally difficult to observe. Static figures—illustrations, diagrams, images—provide opportunities to see relationships in ways that language alone cannot express.

To understand the structure of DNA, students need to visualize not only a static 3-D representation of the phenomenon but also how it might change over time or in accordance with various factors. This approach can be problematic for students when the phenomena under investigation are unseen or at least unobservable within the confines of the classroom. An important component of scientific learning is the ability to "mentally transform 2-D objects into dynamic 3-D objects" (Barnett, Yamagata-Lynch, Keating, Barab, & Hay, 2005, p. 334). Such visualizations are challenging for many students but may be especially difficult for students with learning or cognitive difficulties (Dalton, Morocco, Tivnan, & Rawson Mead, 1997).

For students with cognitive or visual impairments, this critical information may be inaccessible, especially if textbook developers assume that all individuals have equivalent access to the visual and verbal parts of the text (Hegarty, Carpenter & Just, 1991; Kozma, & Russell, 2005; Mayer & Anderson, 1991; Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Shah, Mayer, & Hegarty, 1999; Winn & Soloman, 1993).

Scientific modeling is related to specialized representations, but with important differences. With modeling, students make representations of their world, often based on their knowledge or on data that they have collected (Lehrer & Schauble, 2000), and are encouraged to develop representational approaches that display and solidify their conceptual learning (DiSessa, 2005). Students who develop models of their understanding usually learn that models evolve. As students gain greater understanding, they can refine their models (Bakas & Mikropoulos, 2002; Barab, Hay, Barnett, & Keating, 2000; Chi, Bassok, Lewis, Reimann, & Glaser, 1989; Coll, France, & Taylor, 2005; Gilbert & Priest, 1997; Harrison & Treagust, 2000; Treagust, Chittleborough, & Mamiala, 2002) Students also learn that in science, it is common for models to evolve as new information becomes accepted by communities of scientists.

The physical aspects of modeling present some specific challenges for struggling students. However, the basic concepts of modeling should be accessible to all students because modeling is not entirely visual—it is more than drawing pictures. It is using a visual language to represent abstract concepts concretely (Calabrese Barton, Koch, Contento, & Hagiwara, 2005; Clement, 2000; Duschl, Deaák, Ellenbogen, & Holton, 1999; Nersessian, 2007). Students unable to see the models should be able to understand how they are used. Further, many scientific models can be represented in alternative ways. For example, a food web is used to reason about relationships between consumers and producers and to understand the impacts of various ecological changes. The food web can be represented as a web or as a table without loss of semantic content. Other types of models may require more complex alternative representations, but alternatives often exist.

Educational technologies can make a difference by giving students ways to access and engage in visual representations and modeling, using these materials:

- Universally designed instructional materials
- Materials using the National Instructional Materials Accessibility Standard (NIMAS)
- Tools that provide scaffolds (supports) for student modeling

Universal Design for Learning (UDL) Materials

Universal Design for Learning (UDL) recommends that concepts be presented with multiple means of representation, action, and engagement (Meyer & Rose, 2002). This redundancy helps ensure that students with perceptual disabilities are not limited to one modality (e.g., visual information) to access critical content. It also gives students opportunities to engage with tasks such as modeling by using the methods that are most appropriate for their abilities instead of limiting them to only a visual representation (http://www.cast.org/research/udl/index.html).

The National Instructional Materials Accessibility Standard (NIMAS)

The NIMAS standard is used to provide instructional materials to a central repository (the National Instructional Materials Access Center or NIMAC) in a flexible, uniform manner (XML). From the repository, these materials can be made into alternative, accessible formats (Braille, large print, audio, digital). Publishers provide textbooks and other instructional materials, including workbooks, to the NIMAC in digital form. Requesting organizations then use the files to create accessible products. These files are also available to students who are using technologies on personal computers or special devices that can read the XML files directly. Instructional materials provided through the NIMAC should have textual representations to support students who cannot access the visual material. A wide number of technologies can read these materials (http://nimas.cast.org/).

Scaffolds for Model-Based Reasoning

Some educational software can support students’ use of model-based reasoning by providing scaffolds, or instructional supports. The term is derived from sociocultural theories of learning based on the work of the Russian psychologist Vygotsky (1978). Vygotsky theorized that learning occurs with the help of more knowledgeable others who “scaffold” less knowledgeable learners as they learn new concepts. In some cases, these scaffolds fade as students increase in proficiency (Quintana et al., 2004). Researchers at the University of Michigan and Northwestern University have been developing these tools for use with technology-rich science curricular materials (http://www.umich.edu/~hiceweb/iqwst/index.html).

Implications for Educators

To accommodate struggling students for whom visualization and modeling may be challenging, teachers can consider the following:

- Look for technological resources in the media center and on the Internet that can expose students to more ways of representing the phenomena they are studying.
- Ensure that students understand that scientific visualization and modeling are more than graphical and visual approaches; they allow certain types of collective reasoning and communication.

- Encourage students to discuss and critique some of the approaches to models in textbooks. Ask them why the conventions in the book are used.
- Search the www.TechMatrix.org for tools that are compatible with the NIMAS standard and for curricula built using UDL and/or including scaffolds for scientific reasoning.

Science Literacy, Vocabulary, and Discourse

To be scientifically literate, students must be able to express themselves appropriately. They need to master specific vocabulary. They also need to use it in discourse that occurs in long passages, such as journals or lab reports, and in appropriate contexts (Anderson, Holland, & Palincsar, 1997; Lemke, 1990; Moje, Cllazo, Carillo, & Marx, 2000; National Research Council, 2000; Smith & Anderson, 1999; Tobin, Elmesky, & Carambo, 2002). In *Talking Science*, Lemke (1990) showed that student success is more than a mastery of facts and terms. It is about making scientific expressions in the right way in certain contexts. These skills are especially challenging or present conceptual barriers to students from different cultures and linguistic backgrounds or to those with cognitive and/or language-based challenges.

Struggling students will likely benefit from focused attention on their background knowledge and vocabulary as part of instruction (Heller & Greenleaf, 2008). As students move from general courses to more in-depth and content-laden courses, the specific background knowledge and vocabulary assumed by reading materials and preparation tasks become even more important. This is especially true for students who are English language learners, even if their oral English is quite proficient (Short & Fitzsimmons, 2006). Without the concepts and specific content vocabulary, reading and comprehending challenging texts are very difficult for anyone (Alexander & Jesson, 2000) but are nearly impossible for students already struggling.

Both mainstream and assistive technologies can be used in strategies for teaching struggling students:

- Electronic references
- Multimedia to target background knowledge
- Scientific discourse scaffolds

Electronic Resources

Glossaries, electronic dictionaries, videos, and other online references and simulations give students opportunities to practice using language in authentic ways. These types of resources are the first level of scientific discourse support. They provide students with a way to access more information about a specific term. The Signing Science Dictionary© offers this type of resource for deaf students and their teachers (http://signsci.terc.edu/). Other embedded supports provide similar foundational information for other students.

Multimedia to Target Background Knowledge

Teachers can boost student background knowledge, which may be a weak area for some struggling students. Interactive websites, encyclopedias, and the National STEM Digital Learning (NSDL) network (formerly the National Science Digital Library; http://nsdl.org/), and other free and commercial websites give students opportunities to engage with science content.

Scientific Discourse Scaffolds

This type of software support is a second level of support. It operates at a larger scale than the individual term or phrase, such as presenting an explanation, a conversational turn, or a part of a document. For example, concept-mapping software can help students visualize the structure of science discourse. Writing templates can be used or created by the teacher to illustrate the general structures that students are expected to work within, such as a lab report. These approaches may help students with weak literacy skills and those unfamiliar with formal and scientific uses of language.

Implications for Educators

To accommodate all students, especially those for whom the language of science is a challenge, teachers can try several ways, including technology, to support these students:

- Pre-teach vocabulary and ensure that students understand nuanced meanings, which can improve students' comprehension.
- Use technologies that can strengthen students' background knowledge and vocabulary proficiency.
- Make the expectations of science discourse explicit and let students know that part of succeeding in science both on tests and in life is using the proper language in scientifically appropriate ways.
- Consider developing exercises that will help students strengthen their use of scientific discourse, including modeling correct oral and written expressions.
- Search the www.TechMatrix.org for tools that support scientific discourse and have both the first level of support, such as glossaries, and the second level of discourse scaffolds.

Questions, Argumentation, and Use of Evidence

Over the past 20 years, educators and researchers have looked carefully at science education and how students learn. It is generally accepted that students learn best by doing, particularly in science courses (Dalton et al., 1997). Some science educators stress the importance of having students learn how to engage in signature scientific acts, such as formulating questions and using evidence in arguments, to develop both scientific competency and 21st century skills (Duschl & Osborne, 2002; Krajcik & Blumenfeld, 2006; Marx et al., 1994; White & Frederiksen, 1998). Students who use evidence to make claims and interact with other students who are also presenting evidence-based arguments are engaging in authentic practices as part of scientific communities of practice (Baxter & Glaser, 1995; McNeill & Krajcik, 2008).

In science classrooms where inquiry methods are used, the approach to teaching and learning can look very different from that in traditional classrooms where teachers are trying to transmit knowledge by lecturing and/or having students work through well-defined laboratory projects. In classrooms stressing questions, argumentation, and uses of evidence, students often develop original questions about nature and post those questions for others to see. In these classrooms, students take on the role of critic and defender of positions instead of learning well-established science principles from teachers and textbooks or doing the routine laboratory activities that other classes have done for years. These classes tend to be unique because so much of the content can come from the students themselves.

Classrooms that facilitate collaboration and scientific discourse among students have the added benefit of helping students develop their critical thinking and reasoning skills and encouraging scientific thinking. In a process akin to peer review, students develop questions, present hypotheses and observations, debate conclusions, and use one another's ideas as a jumping off point for their own conclusions (Lajoie, Lavigne, Guerrera & Munsie, 2001). Struggling students may find this process challenging because it requires being able to abstract their own opinions and beliefs from the evidence, comment on the relationship between the evidence and the claims, and use sophisticated and specific language.

Computer-supported collaborative learning (CSCL) uses technology to support students' interactions with important topics. When applied to science education, CSCL presents a type of learning environment where students can pose questions, solve problems, and engage in argumentation both asynchronously and across geographic distance (Scardamalia, Bereiter, McLean, Swallow, & Woodruff, 1989) Though the majority of research on collaborative work among students has focused on collaboration in the physical classroom, the findings can be extrapolated to online environments to hypothesize potential benefits for students, especially struggling students who could benefit from the ability to compose and read responses in text.

Technology can assist students in developing authentic scientific competency in three areas:

- Constructivist tools to support question development
- Scaffolds for evidence construction
- Collaborative science education tools

Constructivist Tools to Support Question Development

Constructivist tools allow students to build their own knowledge structures. They allow students to make predictions and test their hypotheses. Through these activities, students have a structure to engage in the process of being scientists (Krajcik & Blumenfeld, 2006). These types of tools are often found in curricula being developed by researchers, such as the Investigating and Questioning our World with Science and Technology (IQWST) curricula (www.iqwst.org).

Scaffolds for Evidence Assembly and Argumentation

In recent years, some researchers have focused on the discursive practices of how students use evidence and construct an argument by using three main components a claim, evidence, and reasoning (Toulmin, 2003). These practices do not simply focus on students' getting the correct answer. Rather, they focus on students' using their evidence appropriately in a well-reasoned argument, even if the answer is not factually correct (Quintana et al., 2004).

Collaborative Science Education Tools

Although CSCL tools vary in functionality and ease of use, they have several common features. Often these tools function as a common space or forum for users to share ideas. They often resemble Internet bulletin boards or wikis. In one such program, Knowledge Forum (http://www.knowledgeforum.com/), users see a graphical representation of student notes, both their own and those of their peers. Students can post new ideas, respond to the suggestions of others, link to further information, or question a peer's assumptions. As the discussions take place, all users can see the progression of ideas. Data, images, and video clips are saved in a communal database so that students can search and share knowledge (Tan et al., 2005). Other freely available collaborative editing tools (e.g., Google Docs, Google Wave, SubEthaEdit, Etherpad, wikis) could also be used for this purpose with some support and scaffolding from the teacher.

Implications for Educators

To accommodate students for whom authentic scientific activities are challenging, teachers can try the following strategies:

- Use the Internet for web-quests and other ways to allow students to develop and research questions about the subjects they are studying.
- Seek out inquiry-based technology curricula that support students' development of questions and use of problem-based learning.
- Show students how they can construct a scientific argument using evidence, and explain that this process is probably similar to the ways they argue for who is the better artist, sports hero, or media star.

- Use visualization tools, including concept mapping, to develop both interrelated questions and question-boards and structured science arguments that have the main features of a claim, evidence, and reasoning.
- Search the www.TechMatrix.org for tools that support science education and that have authentic project-based and constructivist features.

Student Engagement and Identity with Science

Perhaps one of the most important dimensions of science education for all students is their ability to engage with science as citizens and possibly in science careers (Aikenhead, 2001; Lynch, 2000; Parker, Rennie, & Fraser, 1996). Do students understand the importance of science in their modern lives? Even those for whom science is not their future career can be literate in science and able to engage productively with scientific evidence in media and daily life.

Identity is linked to engagement and motivation. When students see themselves as potential future scientists, they are more engaged in science education. Students who can envision themselves as scientists or mathematicians are more likely to pursue STEM coursework beyond middle and high school (Tai, Liu, Maltese, & Fan, 2006).

Key to both identity and engagement are authentic activities that involve inquiry and active student participation (National Research Council, 1999). Curricula that feature problem-based or project-based learning (PBL) activities can have students play the roles of scientists to answer a question or solve a problem. As students connect with a central problem, or *driving question*, they are more engaged in the learning process, take more control, and are more likely to see their potential as future scientists.

Some features of educational technology that can support students' engagement and identity are these:

- Science curricula that encourage student questioning and an inquiry process
- Scenarios and immersive environments that let students practice being scientists
- Distance technology to connect students with practicing scientists

Inquiry-Based Science Curricula

Technologies that are based on scientific inquiry are more likely to contain a driving question or a project/problem-based design. These tools and curricula are likely to be developed by researchers in the next several years because even though inquiry has been popular for some time, the technologies to support it are now becoming more widely available.

Scenarios and Immersive Environments That Let Students Practice Being Scientists

Scenario-based instructional technologies that provide authentic experiences, including using and manipulating data, producing scientific types of documents, and portraying the user as a scientist, can help students engage in and envision themselves pursuing scientific paths. These can be simulations, such as microworlds or virtual laboratories, or immersive worlds that allow students to explore and learn progressively more complex topics and tasks. Simulations are perhaps the most widely available technology tools for science content at every grade level. They can range from incredibly complex virtual worlds that allow students to explore an ecosystem in depth, such as Second Life users who have recreated Australia's Great Barrier Reef, to more focused simulations, such as the Howard Hughes Medical Institute's Virtual Cardiology Lab (http://www.hhmi.org/biointeractive/vlabs/cardiology/index.html).

Distance Technology

There are many ways to bring real scientists into the classroom. Students can visit official web pages, email questions, and participate in online discussion forums. Research indicates that these types of interactions can support student learning in a variety of ways, such as engaging students, increasing participation in discussions, and encouraging the shared construction of knowledge (Han & Hill, 2007; Wheeler, Yeomans, & Wheeler, 2008). Tools that allow students to participate in actual research with STEM professionals are other options that enable students to engage in a project on multiple levels, as well as offer students a variety of perspectives.

Many research organizations and universities offer outreach programs to allow classes and students to engage in activities and discussions with scientists. Government agencies such as NASA (http://www.nasa.gov/connect/index.html) and the National Park Service (http://www.nps.gov/learn/) connect students with scientists. Some programs allow students to join scientific expeditions virtually in real time through streaming video—the JASON Project (http://www.jason.org) is an example. Each year, using videos, data collection, virtual labs, simulations, and streaming satellite videos of scientists in the field, students participate in ongoing research, interact with researchers, and engage in scientific discourse with their peers.

Implications for Educators

To encourage students who have a difficult time imagining themselves as being able to pursue scientific careers, teachers can consider some of these approaches:

- Look for examples of scientists on the Internet and show how many came from what seemed to be unlikely backgrounds and were successful in science.
- Identify games and simulations that can provide students with opportunities to model being scientists through their virtual activity.
- Identify programs of resources and technologies for aspiring scientists on the Internet that can help students see the type of support they could receive.
- Search the www.TechMatrix.org for tools that support science education, are built using authentic scientific inquiry, and allow students to practice being scientists.

CONCLUSION

This report has presented ways of teaching science and using technology for all students, including those who are struggling. The first area, *Physically Doing Science,* focuses on the physical tasks of science education and how technologies can make this aspect more accessible and attainable for students. The second area, *Visualization, Representation, and Modeling*, examines how students make sense of what they learn. The third area, *Science Literacy, Vocabulary, and Discourse*, addresses the language and literacy skills that students use in speaking and writing as scientists. The fourth area, *Questions, Argumentation, and Use of Evidence,* explores the critical skills that students should master as they understand the work of science. The final section, *Student Engagement and Identity with Science*, discusses how students can consider science accessible and as a possible career.

These five dimensions of science education are inter-related and a way to think about science education as authentic and student centered. The goal of this approach offers facts and content knowledge that are delivered within the context of science as a relevant subject in students' lives. It involves students as both producers and consumers of knowledge and encourages science careers for any student, not just those whose backgrounds and circumstances give them special advantages.

Finally, the approach to technology in this report is consistent with the principles of Universal Design for Learning (UDL). The representation of learning materials in multiple ways can benefit all learners. In addition, using technologies to support inclusive science education can remove barriers and provide multiple learning opportunities for all students.

REFERENCES

Aikenhead, G. S. (2001). Students' ease in crossing cultural borders into school science. *Science Education*, *85*, 180–188.

Alexander, P., & Jesson, T. (2000). Learning from text: A multidimensional and developmental perspective. In M. Kamil, P. Mosenthal, P. Pearson, & R. Barr (Eds.), *Handbook of reading research* (Vol. III, pp. 285–310). Mahwah, NJ: Erlbaum.

Anderson, C., Holland, D., & Palincsar, A. S. (1997). Canonical and sociocultural approaches to research and reform in science education: The story of Juan and his group. *The Elementary School Journal*, *97*(4), 360–383.

Augustine, N. R. (2005). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Bakas, C., & Mikropoulos, T. A. (2002). Design of virtual environments for the comprehension of planetary phenomena based on students' ideas. *International Journal of Science Education*, *25*(8), 949–967.

Barab, S. A., Hay, K. E., Barnett, M., & Keating, T. (2000). Virtual solar system project: Building understanding through model building. *Journal of Research on Science Teaching*, *37*(7), 719–756.

Barnett, M., Yamagata-Lynch, L., Keating, T., Barab, S. A., & Hay, K. E. (2005). Using virtual reality computer models to support student understanding of astronomical concepts. *Journal of Computers in Mathematics and Science Teaching*, *24*(4), 333–356.

Baxter, G., & Glaser, R. (1995). *Cognitive analysis of a science performance assessment* (CREST No. 398). Los Angeles: Center for Research in Evaluation Standards and Student Testing.

Bowker, G. (2006). *Memory practices in the sciences*. Cambridge, MA: MIT Press.

Calabrese Barton, A., Koch, P., Contento, I., & Hagiwara, S. (2005). From global sustainability to inclusive education: Understanding urban children's ideas about the food system. *International Journal of Science Education*, *27*(10), 1163–1186(24).

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*(2), 145–182.

Clement, J. (2000). Model based learning as a key research area for science education. *International Journal of Science Education*, *22*(9), 1041–1053.

Coll, R., France, B., & Taylor, I. (2005). The role of models and analogies in science education: implications from research. *International Journal of Science Education*, *27*(2), 183–198(16).

Collins, A., & Halverson, R. (2009). *Rethinking education in the age of technology: The digital revolution and schooling in America*. New York: Teachers College Press.

Committee on Science, Engineering and Public Policy. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, DC: National Academies Press.

Dalton, B., Morocco, C. C., Tivnan, T., & Rawson Mead, P. L. (1997). Supported inquiry science: Teaching for conceptual change in urban and suburban science classrooms. *Journal of Learning Disabilities*, *30*(6), 670–684.

DeBoer, G. (1991). *A history of ideas in science education: Implications for practice*. New York: Teachers College Press.

Dede, C. (2009). Immersive interfaces for engagement and learning. *Science* (323), 66–69.

DiSessa, A. (2005). Metarepresentation: Native competence and targets for instruction. *Cognition and Instruction*, *22*(3), 293–331.

Duschl, R., & Osborne, J. (2002). Supporting and promoting argumentation discourse. *Studies in Science Education*, *38*, 39–72.

Duschl, R., Deaák, G. O., Ellenbogen, K. M., & Holton, D. L. (1999). Developmental and educational perspectives on theory change: To have and hold, or to have and hone? *Science and Education*, *8*, 525–542.

Gilbert, J., & Priest, M. (1997). Models and discourse: A primary school science class visit to a museum. *Science Education*, *81*(6), 749–762.

Gray, T., Silver-Pacuilla, H., Overton, C., & Brann, A. (2010). *Unleashing the power of innovation for assistive technology*. Washington, DC: American Institutes for Research, National Center for Technology Innovation.

Han, S. Y., & Hill, J. R. (2007). Collaborating to learn, learn to collaborate: Examining the roles of context, community, and cognition in asynchronous discussion. *Journal of Educational Computing Research*, *36*(1), 89–123.

Hardison, J., DeLong, K., Bailey, P., & Harward, V. J. (2006). *Deploying interactive remote labs using the iLab shared architecture*. Paper presented at the ASEE/IEEE Frontiers in Education Conference, Saratoga Springs, NY.

Harrison, A., & Treagust, D. (2000). A typology of school science models. *International Journal of Science Education*, *22*(9), 1011–1026.

Hegarty, M., Carpenter, P. A., & Just, M. A. (1991). Diagrams in the comprehension of scientific texts. In R. Barr, P. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (Vol. 2). New York: Longman.

Heller, R., & Greenleaf, C. (2008). *Literacy instruction in the content areas: Getting to the core of middle and high school improvement*. Washington, DC: Alliance for Excellent Education.

Herrington, J., & Kervin, L. (2007). Authentic learning supported by technology: Ten suggestions and cases of integration in classrooms. *Educational Media International*, *44*(3), 219–236.

Heumann, J. (1999). Inclusion: The challenge, the opportunity. In T. Lombardi (Ed.), *Inclusion: Policy and practice* (pp. 5–18). Bloomington, IN: Phi Delta Kappa Educational Foundation.

Huppert, J., Lomask, S. M., & Lazarowitz, R. (2002). Computer simulations in the high school: Students' cognitive stages, science process skills and academic achievement in microbiology. *International Journal of Science Education*, *24*(8), 803–821.

Hutchins, E. (1996). *Cognition in the wild*. Cambridge, MA: MIT Press.

Individuals with Disabilities Education Act Amendments of 1997, Pub. L. No. 105-17, 20 U.S.C. §1400 et seq., 111 Stat. 37 (1997).

Individuals with Disabilities Education Improvement Act of 2004, Pub. L. No. 108-446, §632, 118 Stat. 2744 (2004).

Kozma, R., & Russell, J. (2005). Multimedia learning of chemistry. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 409–428). New York: Cambridge University Press.

Krajcik, J., & Blumenfeld, P. (2006). Project-based learning. In K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. New York: Cambridge University Press.

Lajoie, S. P., Lavigne, N. C., Guerrera, C., & Munsie, S. D. (2001). Constructing knowledge in the context of BioWorld. *Instructional Science*, *29*, 155–186.

Lehrer, R., & Schauble, L. (2000). The development of model-based reasoning. *Journal of Applied Developmental Psychology*, *21*(1), 39–48.

Lehrer, R., Schauble, L., & Petrosino, A. (2001). Reconsidering the role of experiment in science education. In K. Crowley, C. Schunn, & T. Okada (Eds.), *Designing for science: Implications from everyday, classroom, and professional settings*. Mahwah, NJ: Erlbaum.

Lemke, J. (1990). *Talking science: Language, learning, and values*. Stamford CT: Ablex.

Lemke, J. (2002). *Teaching all the languages of science: Words, symbols, images, and actions.* Paper presented at the La educacion en ciencias, Barcelona, Spain.

Lynch, M., & Woolgar, S. (1990). *Representation in scientific practice*. Cambridge, MA: MIT Press.

Lynch, S. (2000). *Equity and science education reform*. Mahwah, NJ: Erlbaum.

Mancuso, J. C., & Hunter, K. V. (1985). *Constructivist assumptions in the person theories of George A. Kelly and Jean Piaget*. Albany: State University of New York at Albany.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., Blunk, M., Crawford, B., Kelly, B., & Meyer, K. (1994). Enacting project-based science: Experiences of four middle grade teachers. *The Elementary School Journal*, *94*(5), 517–538.

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.

Mastropieri, M., & Scruggs, T. (2000). *The inclusive classroom: Strategies for effective instruction*. Upper Saddle River, NJ: Prentice Hall.

Mastropieri, M., Scruggs, T., & Graetz, J. (2004). Reading comprehension instruction for secondary students: Challenges for struggling students and teachers. *Learning Disability Quarterly*, *26*(2), 103–116.

Mayer, R. E., & Anderson, R. (1991). Animations need narration: An experimental test of a dual coding hypothesis. *Journal of Educational Psychology*, *83*(4), 484–490.

Mayer, R. E., Bove, W., Bryman, A., Mars, R., & Tapangco, L. (1996). When less is more: Meaningful learning from visual and verbal summaries of science textbook lessons. *Journal of Educational Psychology*, *88*(1), 64–73.

McGinnis, J. R. (2006). Preparing prospective science teachers to teach students with developmental disabilities. In D. L. Zeidler (Ed.), *The role of moral reasoning on socioscientific issues and discourse in science education* (pp. 195–216). Dordrecht, The Netherlands: Kluwer.

McGinnis, J. R., & Stefanich, G. P. (2007). Special needs and talents in science learning. In S. K. Abel & N. G. Lederman (Eds.), *Handbook of research in science education* (pp. 287–318). Mahwah, NJ: Erlbaum.

McNeill, K., & Krajcik, J. (2008). Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student learning. *Journal of Research in Science Teaching*, *45*(1), 53–78.

Meyer, A., & Rose, D. H. (2002). *Teaching every student in the digital age: Universal design for learning*. Alexandria, VA: Association for Supervision and Curriculum Development.

Mohan, L., Sharma, A., Cho, I.-Y., Jin, H., & Anderson, C. W. (2006). *Developing a carbon cycle learning progression for K–12*. Paper presented at the National Association for Research in Science Teaching, San Francisco, CA.

Moje, E., Cllazo, T., Carillo, R., & Marx, A. R. (2000). “Maestro, what is quality?”: Language, literacy, and discourse in project based science. *Journal of Research in Science Teaching*, *38*(4), 469–498.

National Longitudinal Transition Study 2 (NLTS-2). (2003). *The achievements of youth with disabilities during secondary school.* Menlo Park, CA: SRI International.

National Research Council. (2000). *Inquiry and the National Science Education Standards: A guide for teaching and learning.* Washington, DC: National Academies Press.

Nersessian, N. (2007). The cognitive-cultural systems of the research laboratory. *Organizational Studies*, *27*(1), 125–145.

Parker, L., Rennie, L., & Fraser, B. (Eds.). (1996). *Gender science and mathematics: Shortening the shadow*. Dordrecht, The Netherlands: Kluwer.

Partnership for Twenty-First Century Skills. (2008). *Education & competitiveness: A resource and policy guide*. Available online at http://www.21stcenturyskills.org/documents/21st_century_skills_education_and_competitiveness_guide.pdf

Piaget, J. (1983). Piaget's theory. In W. Damon (Ed.), *History, theory, and methods. Handbook of child psychology* (Vol. 1, pp. 103–128). New York: Wiley.

Quintana, C., Reiser, B., Davis, E., Krajcik, J., Fretz, E., Duncan, R., et al. (2004). A scaffolding design framework for software to support science inquiry. *Journal of the Learning Sciences*, *13*(3), 337–386.

Robertson, D., Johnston, W., & Nip, W. (1995). Virtual frog dissection—interactive 3D graphics via the web. *Computer Networks and ISDN Systems*, *28*(1-2), 155–160.

Scardamalia, M., Bereiter, C., McLean, C., Swallow, J., & Woodruff, E. (1989). Computer-supported intentional learning environments. *Educational Computing Research*, *5*(1), 51.

Scruggs, T., & Mastropieri, M. (1991). Classroom applications of mnemonic instruction: Acquisition, maintenance, and generalization. *Exceptional Children*, *58*(3), 219–229.

Shah, P., Mayer, R. E., & Hegarty, M. (1999). Graphs as aids to knowledge construction: Signaling techniques for guiding the process of graph comprehension. *Journal of Educational Psychology*, *91*(4), 690–702.

Short, D. J., & Fitzsimmons, S. (2006). *Double the work: Challenges and solutions to acquiring language and academic literacy for adolescent English language learners* (A report to the Carnegie Corporation of New York). Washington, DC: Alliance for Excellent Education.

Simon, H. (1996). *The sciences of the artificial*. Cambridge, MA: MIT Press.

Smith, D., & Anderson, C. (1999). Appropriating scientific practices and discourses with future elementary teachers. *Journal of Research in Science Teaching*, *36*(7), 755–776.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*, *312*, 1143–1144.

Tan, S. C., Yeo, A. C. J., & Lim, W. Y. (2005). Changing epistemology of science learning through inquiry with computer-supported collaborative learning. *Journal of Computers in Mathematics and Science Teaching*, *24*(4), 367–386.

Tobin, K., Elmesky, R., & Carambo, C. (2002). Learning environments in urban science classrooms: Contradictions, conflict and the reproduction of social inequality. In S. W. Goh & M. S. Khine (Eds.), *Studies in educational learning environment: An international perspective* (pp. 101–129). Singapore: World Scientific Publishing Co.

Toulmin, S. (2003). *The uses of argument*. Cambridge, England: Cambridge University Press.

Treagust, D. F., Chittleborough, G. D., & Mamiala, T. L. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education*, *23*(4), 357–368.

Vygotsky, L. (1978). *Mind in Society*. (Trans. M. Cole). Cambridge, MA: Harvard University Press.

Wade, S., & Zone, J. (2000). Creating inclusive classrooms: An overview. In S. Wade (Ed.), *Inclusive education: A casebook and readings for prospective and practicing teachers* (pp. 3–28). Mahwah, NJ: Erlbaum.

Wheeler, S., Yeomans, P., & Wheeler, D. (2008). The good, the bad and the wiki: Evaluating student-generated content for collaborative learning. *British Journal of Educational Technology*, *39*(6), 987–995.

White, B., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition and Instruction*, *16*(1), 3–118.

Winn, W., & Soloman, C. (1993). The effect of the spatial arrangement of simple diagrams on the interpretation of English and nonsense sentences. *Educational Technology Research and Development*, *41*, 29–41.