EDUCATION FOR LIFE AND WORK

Guide for Practitioners

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Contents

Education for Life and Work

Guide for Practitioners

Life in the 21st century requires people to be prepared to fill a variety of roles—as workers, parents, citizens, and consumers—in which they will need to apply their knowledge and skills effectively to rapidly changing situations. Recognizing this need, business, political, and educational leaders are increasingly asking schools to teach students the competencies they will need to navigate a changing world—skills such as problem solving, critical thinking, and collaboration. Such skills are often referred to as "21st century skills," "soft skills," or "deeper learning."

But what do these skills really look like? Can they be taught in school, and if so, how can they be taught? Is it more effective to teach them in addition to core school subjects or as part of them?

A report from the National Research Council, *Education for Life and Work: Developing Transferable Knowledge in the 21st Century,* explores what research has found about these questions and this type of learning. The report clarifies the meaning of "deeper learning" and "21st century skills" and identifies teaching approaches that are effective in supporting deeper learning. The report represents the consensus of a panel of diverse experts in education, psychology, and economics.

This booklet summarizes the key information in that report and describes effective teaching approaches. It analyzes deeper learning in the context of English language arts, mathematics, and science. And it identifies areas of convergence with the learning goals set for mathematics and English language arts by the new Common Core State Standards and for science as outlined in the National Research Council's *Framework for K-12 Science Education.* It also outlines the kinds of changes needed in the overall educational system to give all students the opportunity to develop the competencies they need in today's world.

This booklet is intended to be a useful resource for state and district curriculum planners, educational administrators, and supervisors of English language arts, science, and mathematics instruction. Although it is not intended as a "how to" manual for the classroom, it may also be of interest to teachers as they plan student lessons.

The Roots of Deeper Learning

Although calls for deeper learning and the development of 21st century skills have intensified recently, the desire for students to develop transferable knowledge and skills is not new. The idea of deeper learning has its roots in what the mid-20th-century Gestalt psychologists called "meaningful learning," which they distinguished from rote learning. Meaningful learning includes understanding of the deeper structure of problems and the methods used to solve them, enabling students to transfer their knowledge and skills to new problems. In contrast, rote learning—simply knowing facts or how to follow procedures—does not lead to transfer.

Deeper Learning and 21st Century Competencies: An Overview

Research shows that problem solving, critical thinking, and other "21st century skills" are best developed in the context of teaching and learning academic subjects. In fact, research shows that they are key to helping students truly master academic subject matter.

Deeper learning is the process through which a person becomes capable of taking what was learned in one situation and applying it to new situations—in other words, learning for "transfer." Through deeper learning, students develop expertise in a particular discipline or subject area that goes beyond memorization of disparate facts or rote procedures; they also understand when, how, and why to apply what they know. They recognize when new problems or situations are related to what they have previously learned, and they can apply their knowledge and skills to solve them.

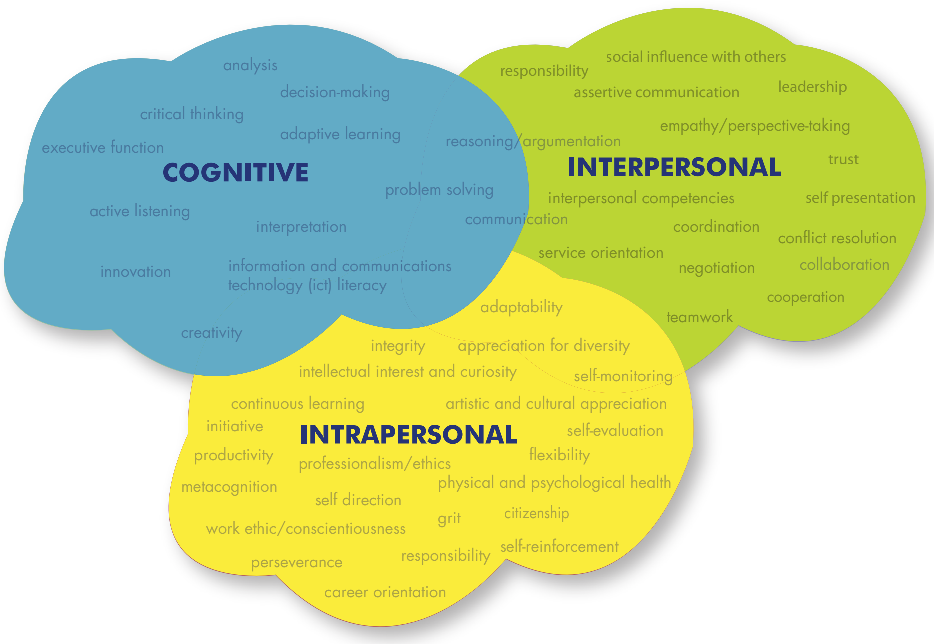
Consider, for example, what it would mean for a student to engage in deeper learning about the concepts of means, medians, and modes in mathematics. The student would understand not only how to calculate these values, but also how and in what circumstances each is best used. If the student later worked at a store that tracked average daily sales each month, he or she would likely recognize that a special sale on the first day of a particular month would skew the average and that an alternative measure, such as the median, might better represent daily sales for that month. In contrast, a student who had only memorized the formulas for calculating means, medians, and modes probably would not know which measure to use. The successful student has transferred knowledge to a new application or situation—in this case, to solve a problem at the store.

Through the process of deeper learning, students develop **21st century competencies**—which encompass both knowledge and skills—that can be transferred to new situations or problems within a subject or field. In contrast to a view of 21st century skills as general skills that can be applied to a range of different tasks in various civic, workplace, or family contexts, research so far suggests that these competencies are specific to—and intertwined with—knowledge of a particular discipline or subject area.

Many individuals and organizations have proposed lists of competencies that they believe to be important for the 21st century. The competencies vary widely, ranging from critical thinking and argumentation to flexibility and empathy. They can be organized into three domains:

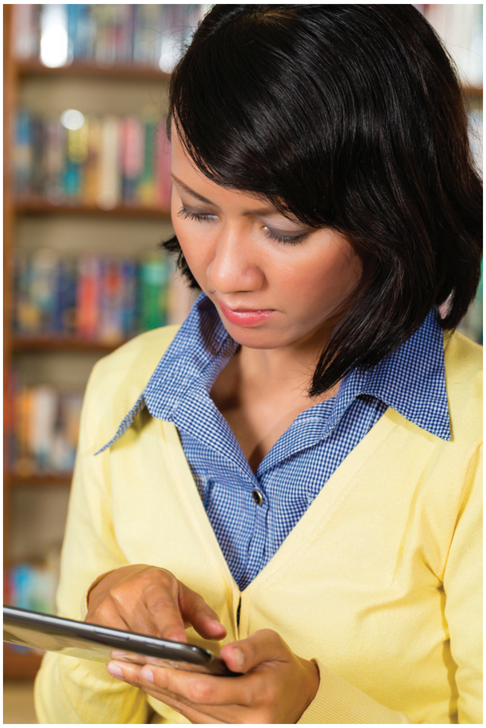
- the cognitive domain, which includes thinking, reasoning, and related skills;
- the intrapersonal domain, which involves self-management, including the ability to regulate one's behavior and emotions to reach goals; and
- the interpersonal domain, which involves expressing information to others, as well as interpreting others' messages and responding appropriately.

Although research on how these various 21st century competencies are related to desired outcomes in education, work, and other areas of life has been limited, there are some promising findings. Cognitive competencies, which have been the most extensively studied, show consistent, positive correlations of modest size with students' achieving higher levels of education, higher earnings, and better health. Among intrapersonal



"21st century skills" grouped into three broad domains

competencies, conscientiousness—which includes such characteristics as being organized, responsible, and hard-working—shows the strongest relationship with the same desirable outcomes. Conversely, antisocial behavior, which reflects deficits in both intrapersonal skills (such as self-regulation) and interpersonal skills (such as communication), is related to poorer outcomes.



More research is needed to increase our understanding of relationships between particular 21st century competencies and desired adult outcomes—and especially to look at whether the competencies are causing the desired outcomes rather than simply correlated with them. This much is known, however: Mastery of academic subject matter is not possible without deeper learning. In the next section of the booklet we consider the process of deeper learning and how 21st century competencies develop.

How Far Can Skills and Knowledge Transfer?

As we note above, many advocates for 21st century skills expect that students can learn general skills—such as complex problem solving or argumentation—that can be transferred to a wide range of tasks in various academic, civic, workplace, or family contexts. Yet over a century of research has yielded little evidence that individuals can develop general-purpose cognitive competencies that are transferable to any new discipline, problem, or context, in or out of school. For example, there is no evidence that learning how to solve problems in geometry will aid problem-solving in history or literature or in a friendship. What research does show is that students can learn to transfer knowledge and skills within a subject area or discipline when effective teaching methods—like those described in this booklet—are used.

A Closer Look at Deeper Learning

Deeper learning is the process by which students develop expertise in a subject area. An extensive body of cognitive research has demonstrated that what distinguishes experts from novices is not simply general mental ability, such as memory or intelligence. Unlike novices, experts have acquired large stores of knowledge and skills in a particular subject area, as well as strong problem-solving techniques that are specific to that subject area. Perhaps more significantly, they have organized and stored this knowledge in ways that make it readily retrievable and useful. Studies of expertise in fields ranging from medicine to music have shown repeatedly that experts have in their long-term memories large banks of well-organized facts and procedures and, particularly, deep specialized knowledge of their subject matter.

Experts have efficiently coded and organized this information in their memories in ways that help them interpret new information in light of what they already know. When confronted with a new situation or problem in their field, they notice features and meaningful patterns of information that are frequently overlooked by novices in the field. That is, experts recognize when a new situation is similar in principle to a kind of problem they already know how to solve.

Rather than simply remembering sets of isolated facts or propositions, experts store their structured knowledge in a way that closely links it with contexts and conditions for its use. Because the experts' knowledge is "conditionalized" in this way, they do not have to search through the vast repertoire of everything they know when confronted with a problem. Instead, they can readily activate and retrieve the subset of their knowledge that is relevant to the task in front of them.

This understanding of how experts solve new problems provides a goal for teaching: To aid deeper learning, teachers should help students understand the conditions for applying the knowledge and procedures they learn. Assessments should address whether students know when, where, and how to use their knowledge.

Novices vs. Experts

Novices…	Experts…
Store facts as isolated units	Store facts in an interconnected network
Create categories based on surface features	Create categories based on deep structural features
Need to expend conscious effort in applying procedures	Have automated basic procedures, freeing them from the need to expend conscious effort on them
Use general problem-solving strategies	Use specific problem-solving strategies tailored to specific kinds of problems in a discipline
May hold unproductive beliefs, such as the idea that performance depends on innate ability	Hold productive beliefs, such as the idea that if they try hard enough they can solve the problem

Practice and Feedback

Developing transferable knowledge, such as that exhibited by experts, takes time and focus and requires many opportunities for practice—especially practice with feedback. Acquiring new skills and knowledge in a subject area often requires hundreds or thousands of instances of practice in retrieving relevant knowledge or executing a procedure. This finding is true across a broad range of tasks, from typing on a keyboard to solving geometry problems. Some educators worry that time spent developing this type of fluent expertise with foundational concepts and skills is detrimental to such goals as the development of critical and creative thinking or the ability to solve nonroutine problems. However, research shows that intense practice actually provides an essential basis that enables more complex and sophisticated reasoning and performance in a field.

Early in the learning process, performance requires effort because it depends heavily on a person's working memory. People have to create a mental representation of the task they are supposed to perform and often "talk their way through the task" while executing it. Once the skills and knowledge needed for the task are in a person's long-term memory, heavy reliance on working memory and its limited capacity can be bypassed. As a result, performance of the task becomes fluent and then automatic, and the person's mental capacity is available to focus on other matters.

The research is clear that receiving feedback during practice is critical to acquiring a skill. Learners need feedback about the correctness of what they have done. If their work is incorrect, they need to know the nature of the mistake. Practice without feedback produces little learning. One of the persistent dilemmas in education is that students often spend time practicing incorrect skills with little or no feedback. Unguided practice—for example, homework in mathematics—can in effect be practice in doing something incorrectly, especially for students who are struggling with the subject.

The type of feedback matters too: Feedback that explains why a practice is incorrect is more valuable for learners than feedback that simply flags errors. Research demonstrates that explanatory feedback is valuable in both traditional and digital learning environments. For example, one study compared two different versions of an interactive science learning game in which students traveled to planets with different environmental conditions and were asked to design a plant that could survive in those conditions. When the students were tested to measure how well they retained the intended ecological concepts and transferred them to new plant-design problems based on the same general principles, the students who received explanatory feedback performed significantly better than those who were given only corrective feedback.

In summary, deeper learning requires that students learn not only facts and procedures, but also the general principles underlying them and when and why to apply particular procedures and knowledge. Acquiring deeper learning requires extensive practice with explanatory feedback that helps learners understand and correct errors and so practice correct procedures.

Deeper Learning and Memory

Whether a piece of knowledge or a procedure can be transferred to a new situation depends largely on whether it is stored in a person's long-term memory in a way that lets the person's working memory have access to it when it is relevant and needed.

Working memory is what people use to process and act on information immediately before them; it is a conscious system that receives input from the sensory systems and also from the long-term memory. Unlike long-term memory—which is an effectively limitless store of information—working memory can only hold and process a limited amount of information at any time. Drawing on long-term memory can sometimes help overcome the limits of short-term memory; for example, although few people can remember a randomly generated string of 16 numbers, anyone with some knowledge of American history is likely to be able to recall the string 1492-1776-1865-1945.

What matters most in learning situations is not the capacity of working memory, but how well one can evoke the knowledge stored in long-term memory and apply it to new situations and problems when they arise. Deeper learning allows students to store knowledge in their long-term memories that is structured around the underlying principles in a subject area, making the knowledge easy to retrieve and apply. In other words, they store knowledge the way experts do.

Teaching to Support Deeper Learning: Key Practices

How can teachers aid students' deeper learning of subject matter and promote transfer? Addressing this seemingly simple question has been a central task of researchers for more than a century, and in the past several decades they have made progress toward evidence-based answers.

Applying the instructional principles below will aid students' deeper learning of subject-matter content in any discipline. Because deeper learning takes time and repeated practice, instruction aligned with these principles should begin in preschool and continue across all levels of learning, from kindergarten through college and beyond. Teaching in these ways will make it more likely that students will come to understand the general principles underlying the specific content they are learning and be able to transfer their knowledge to solve new problems in the same subject area.

These principles and practices are based on research in the cognitive domain. They have not been studied in terms of developing transferable competencies in the interpersonal and intrapersonal domains, but it is plausible that they are applicable.

Use multiple and varied representations of concepts and tasks, and help students understand how different representations of the same concept are "mapped" or related to one another. Research has shown that adding diagrams to a text or adding animation to a narration that describes how a mechanical or biological system works can increase students' performance on a subsequent problem-solving transfer test. In addition, allowing students to use concrete objects to represent arithmetic procedures has been shown to increase their performance on transfer tests. This finding has been shown both in classic studies in which bundles of sticks are used to represent two-column subtraction and in an interactive, computer-based lesson in which students move a bunny along a number line to represent addition and subtraction of numbers.

Encourage elaboration, questioning, and self-explanation. The techniques of elaboration, questioning, and self-explanation require students to actively engage with the material—going beyond memorizing to process the content in their own words. Some specific techniques that have been shown to aid deeper learning include:

- prompting students who are reading a text to explain the material to themselves aloud, in their own words, as they read;
- asking students certain questions about material they have just read or been taught—such as why, how, what if, what if not, and so what;
- using teaching practices that establish classroom norms of students' questioning each other and justifying their answers;
- asking learners to summarize what they have learned in writing; and
- having students test themselves without external feedback, for example, by asking themselves questions about material they have just read.

Engage learners in challenging tasks, with supportive guidance and feedback. Over 40 years of research has shown that asking students to solve challenging problems in science and other disciplines without appropriate guidance and support is ineffective at promoting deeper learning. In contrast, asking students to solve challenging problems while providing specific cognitive guidance along the way does promote deeper learning. For example, there is no compelling evidence that beginners deeply learn science concepts or processes simply by freely exploring a science simulation or game, but if they receive guidance in the form of advice, feedback, and prompts—for example, completing part of the task for the learner—they are more likely to learn the content deeply.

Teach with examples and cases. Using examples and cases can help students see how a general principle or method is relevant to a variety of situations and problems.

One approach is a worked-out example, in which a teacher models how to carry out a procedure—for example, solving probability problems—while explaining it step by step. Offering worked-out examples to students as they begin to learn a new procedural skill can help them develop deeper understanding of the skill. In particular, deeper learning is facilitated when the problem is broken down into conceptually meaningful steps that are clearly explained; the explanations are gradually taken away with increasing practice.

Prime student motivation. Another way to promote deeper learning is to prime students' motivation so that they are willing to exert the effort to learn. Research shows that students learn more deeply when they:

- attribute their performance to effort rather than to ability;
- have the goal of mastering the material rather than the goal of performing well or not performing poorly;
- expect to succeed on a learning task and value the learning task;
- believe they are capable of achieving the task at hand;
- believe that intelligence is changeable rather than fixed; and
- are interested in the task.

There is promising evidence that these kinds of motivational approaches can be fostered in learners through such techniques as peer modeling. For example, elementary school students showed increased self-confidence (an intrapersonal competency) for solving subtraction problems and increased test performance after watching a peer demonstrate how to solve subtraction problems while exhibiting high self-efficacy (such as saying "I can do that one" or "I like doing these").

Use formative assessment. A formative assessment is one that is used throughout the learning process to monitor students' progress and adjust instruction when needed, in order to continually improve student learning. It is different from traditional "summative" assessment, which focuses on measuring what a student has learned at the end of a set period of time. Deeper learning is enhanced when formative assessment is used to:

- make learning goals clear to students;
- continuously monitor, provide feedback, and respond to students' learning progress; and
- involve students in peer- and self-assessment.

These uses of formative assessment are grounded in the research demonstrating that practice is essential for deeper learning and skill development, while practice without feedback yields little learning.

Deeper Learning in the Disciplines

Deeper learning and the development of 21st century competencies do not happen separately from learning academic content. Rather, deeper learning enables students to thoroughly understand academic content and to recognize when, how, and why to apply that content knowledge to solve new problems. This section explores what deeper learning looks like in three subjects: English language arts, mathematics, and science.

For each of these subjects, new standards documents have recently been introduced that will likely shape instruction for many years to come: the Common Core State Standards in English language arts and in mathematics, and the Next Generation Science Standards (based on National Research Council's *Framework for K-12 Science Education*). We consider these these standards documents in terms of the goals for deeper learning and 21st century skills.

Deeper Learning in English Language Arts

Discussions of how to teach reading and writing in the United States have a reputation for contentiousness, as reflected in the military metaphors used to describe them, such as "the reading wars." Those "wars" reflect the two ends of a wide spectrum of opinions about how to develop reading for understanding. One approach, which can be called the simple view of reading, holds that reading comprehension is the product of listening comprehension and decoding. Its proponents argue that students in the early grades should learn all of the letters of the alphabet and their corresponding sounds to a high degree of accuracy, until they are automatic. After the code is mastered, students will further their ability to read for understanding through wide reading of literature and nonfiction to gather new ideas about the world and about the disciplines.

The opposite position, which might best be called the utilitarian view of reading and writing, instead starts with the ultimate goal of reading in order to motivate children to learn the basic elements of reading. Proponents argue that, beginning in kindergarten, educators should engage children in a quest to make sense of their world through deep engagement with the big ideas that have puzzled humankind for centuries. Then, as they seek new information to understand and shape their world, students will need to use and refine their reading and writing skills. Once students feel the need to learn to read, proponents say, it will be much easier to teach them the decoding and other basic skills they need to transform print into meaning.

Rather than solidly favoring either of these approaches, the research consistently supports a balanced position that includes both approaches. This balance strongly stresses the basic skills of phonemic awareness, alphabet knowledge, and decoding for accurate word learning in the early stages of reading development, but places an equal emphasis on reading for meaning at all stages of learning to read. Although there is strong support for emphasizing the basics in the all-important early stages of reading, this emphasis need not preclude monitoring one's reading and writing to see if it makes sense or transferring the reading competencies to disciplinary learning tasks. As students mature and the demands of school curriculum focus more on acquiring disciplinary knowledge, the emphasis on reading for meaning increases.

The Four Resources Model

The four resources model, developed by Australian scholars Freebody and Luke in the 1990s, can be useful in understanding the meaning of deeper learning in the context of English language arts. The model is a set of four different stances that readers can take toward a text, each of which approaches reading differently. A reader can assume any one of these four stances in the quest to make meaning in response to a text.

- The reader as **decoder** asks: What does the text say? In the process, the reader builds a coherent understanding of the text by testing each idea encountered for its coherence with all of the previous ideas in the text.

- The reader as **meaning maker** asks: What does the text mean? In answering that question, the reader seeks to develop meaning based on a) the ideas in the text itself, and b) the reader's prior knowledge.

- The reader as **text analyst** asks: What tools does the author use to achieve his or her goals and purposes? The text analyst considers how the author's choice of words, form, and structure shape our regard for different characters or our stance toward an issue, a person, or a group. The reader goes beyond the words and tries to evaluate the validity of the arguments, ideas, and images the author presents.

- The reader as **text critic** asks questions about intentions, subtexts, and political motives. The text critic assumes that no texts are ideologically neutral, asking such questions as: Whose interests are served or not served by this text? Who is privileged, marginalized, or simply absent? What are the political, economic, epistemological, or ethical goals of the author?

Reading and writing are simultaneously code breaking, meaning making, analytic, and critical activities. The stance a reader takes can change from text to text, situation to situation, and even moment to moment when reading a text. Which stance dominates at a particular moment depends on many factors, including the reader's level of knowledge about and interest in the topic and the purpose of the particular reading task.

Drawing on the four resources model, deeper learning in English language arts can be defined from two perspectives: (1) as favoring activities that are successively higher on the list—those in which the reader acts as meaning maker, text analyst, or text critic; or (2) as favoring the management of all four stances based on the reader's assessment of the difficulty of the text or task and the purpose of the task; in other words, deeper learning means that a student understands when and why it is appropriate to use each stance, as well as how to do so.

These two approaches are not mutually exclusive. Deeper learning could involve selecting a stance that elicits the skills and processes that best fit the situation or problem that a reader faces at a given moment *and* suggest a preference for incorporating the higher levels—those of the text analyst and critic—whenever it is possible and appropriate to do so.

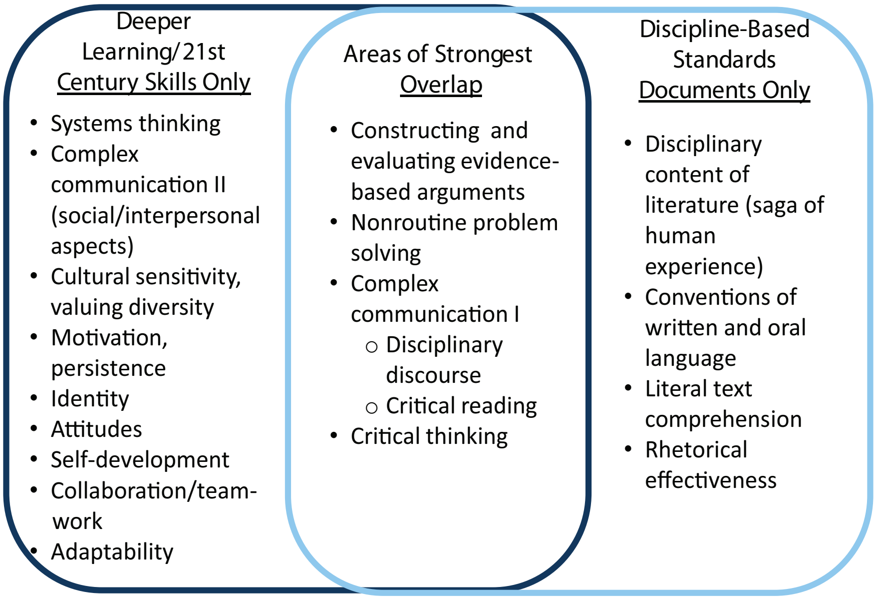
Deeper Learning in the English Language Arts Common Core

The widely adopted Common Core State Standards in English language arts are highly supportive of deeper learning, as reflected in the four resources model. For example, the 10 college and career readiness "anchor standards," which represent what high school graduates should know and be able to do, require students to be able to take all four stances toward a text: decoder, meaning maker, analyst, and critic.

The standards address the basics—including phonemic awareness, phonics, and fluency—primarily in the foundational skills addendum to the standards for kindergarten through grade 5 (K-5). The standards also ask students to apply their developing reading skills to acquire disciplinary knowledge in literature, science, and history, especially in grades 6 through 12—a significant shift away from treating reading as a separate subject.

The domain of cognitive competencies—including such skills as nonroutine problem solving and critical thinking—is well represented in the standards, as the figure on the next page shows. In contrast, serious consideration of the interpersonal and intrapersonal domains is missing. However, recent research in English language arts demonstrates the potential for developing competencies in these domains, as the example described in the box reveals. The example also illustrates the way in which the standards engage students in using reading, writing, and language practice to acquire knowledge of the disciplines. These opportunities for additional practice of English language arts support deeper learning and transfer.

English Language Arts



Overlap between ELA Common Core State Standards and 21st-century skills

Deeper Learning in the Classroom: Seeds of Science – Roots of Reading

The Common Core State Standards in English language arts promote the idea that reading, writing, and language are best taught, practiced, and learned when they are used as tools to acquire knowledge in disciplinary contexts, such as science, history, and literature.

One example of this approach is a curriculum developed by researchers at the University of California-Berkeley's Lawrence Hall of Science and Graduate School of Education, who worked with elementary classroom teachers on a National Science Foundation-sponsored curriculum that helps students use reading and writing to acquire science knowledge, strategies for inquiry, and argumentation skills.

The program, *Seeds of Science—Roots of Reading,* combines hands-on science activities—for example, designing mixtures such as glue or hair gel from everyday household ingredients—with a host of reading, writing, and discussion activities that support students' investigations. Over the course of an 8-week topical unit, students read nine different types of books about various aspects of the topic, including reference books, brief biographies of scientists, and books that connect the science topic to everyday life. For example, students' exploration of a "mystery" sand is paired with a biography of a sand scientist that describes how he investigates the size, texture, color, and origin of sand.

The students have science journals and write almost daily about their learning. And they engage in spirited discussions and debates about unsettled issues that arise from their investigations or readings: for example, they might hold a debate about the origin of the mystery sand. In a typical week, students will spend about 50 percent of their time in science activities and about 50 percent in reading, writing, and discussions about their activities.

The curriculum is designed to foster deeper learning in the cognitive domain through the reading, writing, and inquiry activities. At the same time, the group and individual activities support the development of intrapersonal competencies, such as persistence and taking personal responsibility for one's learning. Interpersonal competencies are supported by the discussions, the small group collaborative investigations, and even in the division of labor students work out for extended investigations or projects. Reflection activities encourage students to think about their own learning, how well the people in their group cooperated, and how they could improve their discussions.

The approach was tested in 94 4th-grade classrooms in one southern state. One-half of the teachers were randomly assigned to teach the integrated science-literacy curriculum. The other half taught the two topics separately, covering the same science content with materials provided by their school districts, along with their regular English instruction. The two groups had comparable gains in science reading comprehension. But the students in the integrated lessons made significantly greater gains on measures of science understanding, science vocabulary, and science writing.

The results from this experiment and similar research show that cognitive outcomes need not suffer—and, indeed, can prosper—when they are taught and learned in a context in which interpersonal and intrapersonal competencies are equally emphasized. Such examples also demonstrate that some disciplines—in this case, English language arts—can benefit from being taught in the context of another discipline, such as science. Similar curricula that integrate English language arts in the disciplines of literature and social studies have also proven effective.

Deeper Learning in Mathematics

Current U.S. teaching practices for mathematics often are at odds with approaches that would support deeper learning and transfer. Studies of upper elementary school and middle-grade classrooms have revealed that students generally work alone on low-level tasks that require memorizing and recalling facts and procedures—the hallmarks of rote learning. They do not engage in the high-level cognitive processes that are the hallmarks of deeper learning, such as reasoning about ideas and solving complex problems.

Although this pervasive approach to mathematics teaching has not been directly established as the cause of the generally low levels of achievement in mathematics by U.S. students, it is difficult to deny the plausibility of such a connection. In response, an array of reform initiatives has been aimed at changing how mathematics is taught and learned in American schools.

While the reformers disagree over some issues, they share the goal of giving students more opportunities to learn what is called "mathematics with understanding." Studies over the past 60 years provide a solid body of evidence about the benefits of teaching mathematics in this way.

Hallmarks of teaching mathematics for understanding include using:

(1) Cognitively demanding mathematical tasks drawn from a broad array of content areas. Although research has shown that it is not easy for teachers to use cognitively demanding tasks well in classrooms, those tasks can lead to increased student understanding, the development of problem solving and reasoning, and greater overall student achievement.

(2) Teaching practices that support collaboration and mathematical discourse among students and that engage them in mathematical reasoning and explanation, consideration of real-world applications, and use of technology or physical models.

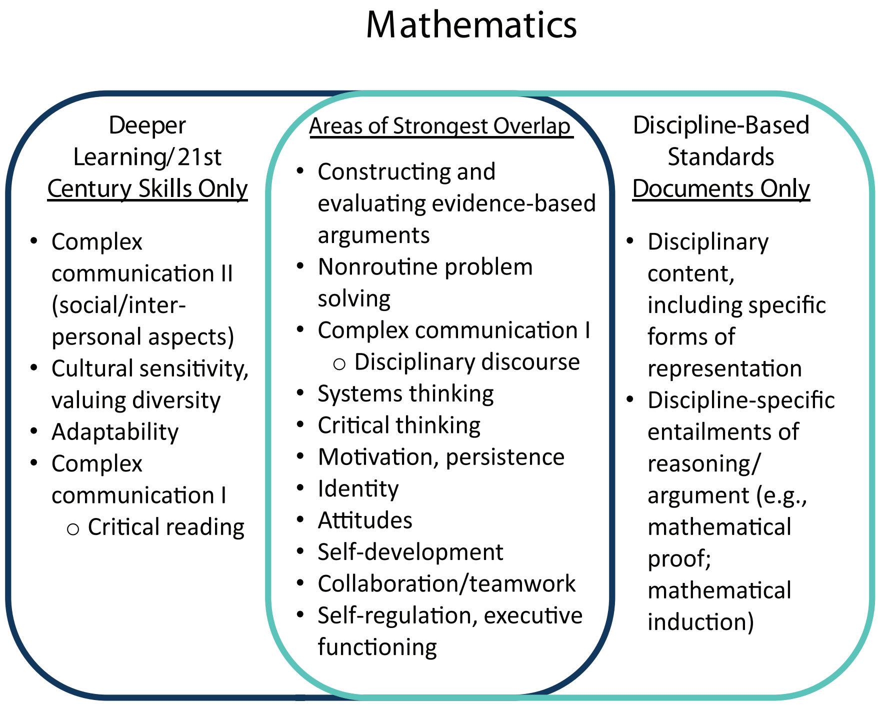
The latest reform effort aimed at the goal of mathematics for understanding has been the Common Core State Standards for Mathematics. If widely implemented, the new standards would enable a giant leap forward in the development of mathematics with understanding.

Deeper Learning in Common Core Mathematics Standards

The new Common Core standards emphasize deeper learning of mathematics, learning with understanding, and the development of usable, transferable mathematics competencies. The standards identify several important learning goals: critical thinking, problem solving, constructing and evaluating evidence-based arguments, systems thinking, and complex communication.

The new standards correspond most strongly with 21st century competencies in the cognitive domain, as shown in the figure on the next page. The two most prominent areas of overlap are in the themes of argumentation/reasoning and problem solving. These themes are central to mathematics and have long been viewed as key leverage points in efforts to teach mathematics for understanding. The theme of argumentation/reasoning is explicitly stated in two of the standards for mathematical practice: "Reason abstractly and quantitatively" and "Construct viable arguments and critique the reasoning of others." The standards also deal explicitly with problem solving; the first standard in the category of mathematical practice is "Make sense of problems and persevere in solving them."

Unlike competencies in the cognitive domain, those in the intrapersonal and interpersonal domains are not particularly prominent in the standards. However, the standards for mathematical practice give some attention to the intrapersonal competencies of self-regulation, persistence, and the development of an identity as someone who can do mathematics.



Overlap between Common Core State Standards in Mathematics and 21st century skills

Deeper Learning in the Classroom: Number Worlds

Although deeper learning in current early-grade mathematics classrooms is rare, a research-based program called Number Worlds has been implemented and studied in pre-K through grade 2. The program is based on six guiding principles:

- Expose children to the major ways numbers are represented and talked about.
- Provide opportunities to link the "world of quantity" with the "world of counting numbers" and the "world of formal symbols."
- Provide visual and spatial analogs of number representations that children can actively explore in hands-on fashion.
- Engage children and capture their imagination so that the knowledge constructed is embedded not only in their minds, but also in their hopes, fears, and passions.
- Provide opportunities to acquire computational fluency as well as conceptual understanding.
- Encourage the use of metacognitive processes—such as problem solving, communication, and reasoning—that will facilitate the construction of knowledge.

To implement the first principle, children explore five different "worlds" or lands at each grade level. In each land, they learn about a particular form of number representation while addressing specific developmental milestones for that grade level. They begin in "object land," where they initially work with real objects and then move on to work with pictures of objects. Next, they visit "picture land," where numbers are represented as semi-abstract patterns of dots that are equivalent to mathematical sets. By playing various card and dice games, the students gradually come to think of these patterns in the same way they think of the words they use to talk about numbers. Third, they explore "line land," where numbers are represented as segments along a line, and they play linear board games. The last two worlds are "sky land," where students see numbers represented with vertical bar graphs and scales, and "circle land," where students learn that numbers are used to measure time and the seasons of the year with sundials and clocks.

All of the activities are designed to help early elementary students mentally link physical quantities with counting numbers and formal symbols (following guiding principle two). For example, in the game "Plus Pup," the teacher and children start by putting a certain number of cookies into a lunch bag, and then the teacher or child takes a walk with the bag. Along the way, he or she picks up the Plus Pup card, and receives one more cookie. The teacher then invites the children to figure out how many cookies are in the bag. At first, the children open up the bag and count the cookies, but as they continue to replay the game, they gradually realize that the Plus Pup card always represents the addition of one more cookie, so they no longer need to open the bag to find the answer.

The program nurtures some interpersonal and intrapersonal competencies along with cognitive ones. For example, to support metacognitive processes (guiding principle six), the program includes question cards that draw children's attention to the changes in quantities during their games and prompt children to perform any calculations necessary to answer the questions. Additional follow-up questions encourage children to reflect on their reasoning. Although the teacher usually begins by using the question cards, over time the children gradually begin to pose the questions themselves, assuming greater responsibility for their own learning.

Deeper Learning in Science

As with English language arts and mathematics, how best to teach science has often been a matter of controversy. Conflicts over science education have traditionally been about the relative importance of content (facts, formulas, concepts, and theories) and process (scientific method, inquiry, and discourse).

Historically, science teaching in U.S. classrooms placed a heavy emphasis on content—generally in the form of memorizing isolated facts. In an attempt to correct this overemphasis, reformers in the 1990s aimed to transform science education by placing a greater emphasis on "inquiry."

This emphasis on inquiry, however, has led to unintended consequences due to insufficient understanding of the nature of scientific inquiry. Inquiry came to be associated primarily with hands-on science. While hands-on activities can be effective if they are designed with clear learning goals in mind and are thoughtfully integrated with learning of science content, such integration is not typical in U.S. high schools. Instead, overemphasis on hands-on activities has led to the neglect of other aspects of scientific inquiry such as critical reasoning, analysis of evidence, development of models, and written and oral discourse.

In addition, some advocates for hands-on science have tended to treat scientific methodology as divorced from content. Many students, for instance, are introduced to a generic "scientific method," which is presented as a fixed linear sequence of steps that students are often asked to apply in a superficial or scripted way, designed to produce a particular result. This approach to the scientific method often distorts the processes of inquiry as they are actually practiced by scientists.

In the work of scientists, content and process are not disconnected. Rather, they are deeply intertwined: Scientists view science as both a body of established knowledge and an ongoing process of discovery that can lead to revisions in that body of knowledge. Sophisticated science learning involves students' learning both content knowledge and process skills in a simultaneous, mutually reinforcing way.

Science in Current Classrooms

As with mathematics, today's science classrooms generally do not reflect the research on how students learn science. The standard curriculum has been criticized as being "a mile wide and an inch deep." Large science textbooks cover many topics with little depth, providing little guidance on how to place the learning of science concepts and processes in the context of meaningful real-world problems. As teachers try to cover the broad curriculum, they give insufficient attention to students' understanding and instead focus on superficial recall-level questions.

Similarly, at the high school level, laboratory activities that typically take up about one science class period each week are disconnected from the flow of science instruction. Instead of focusing on clear learning objectives, laboratory manuals and teachers often emphasize procedures, leaving students uncertain about what they are supposed to learn. Furthermore, these activities are rarely designed to integrate the learning of science content and processes. During the rest of the week, students spend time listening to lectures, reading textbooks, and preparing for tests that emphasize recall of disparate facts.

Making matters worse, during the past decade time and resources for science education have often been cut back because of the No Child Left Behind law. Because science test scores are not counted in the formulations for whether schools are making adequate yearly progress under the legislation, the emphasis in schools has been on English and mathematics.

Deeper Learning in the K-12 Science Education Framework

An attempt to better integrate scientific content and processes and to focus on depth rather than breadth of knowledge began with the 2011 release of the National Research Council's *Framework for K-12 Science Education*. The framework explains in detail what all students should know and be able to do in science by the end of high school. Standards based on the framework have been developed by a group of states, coordinated by the nonprofit organization Achieve.

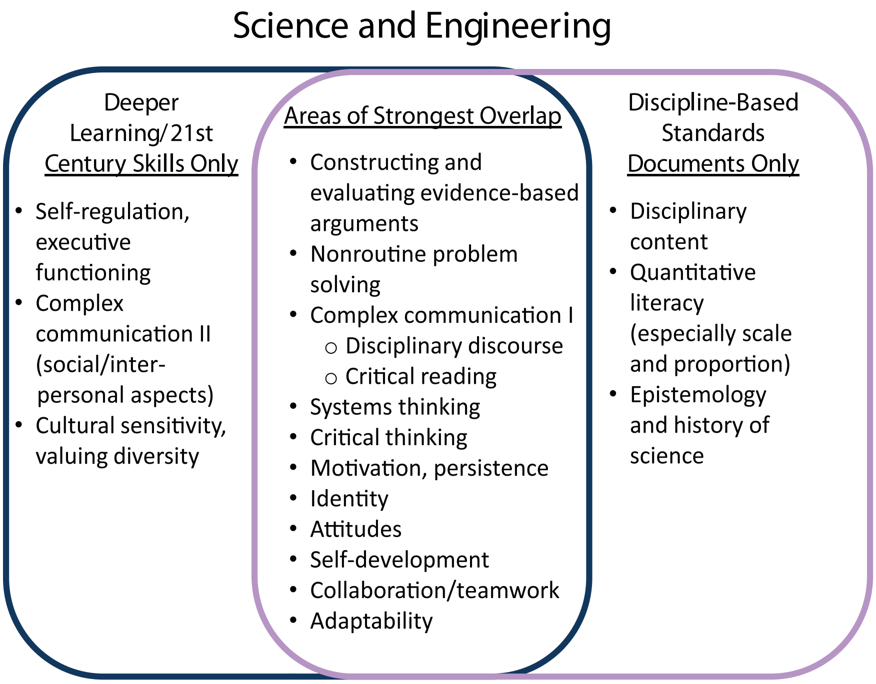
An overarching goal expressed in the framework is to ensure that all students—whether or not they pursue careers in the fields of science, technology, engineering, and mathematics (STEM)—have "sufficient knowledge of science and engineering to engage in public discussions on related issues, are careful consumers of scientific and technological information related to their everyday lives, and are able to continue to learn about science outside of school." In other words, the goal is the development of transferable science knowledge.

The framework has three dimensions, which are conceptually distinct but are integrated in practice in the teaching, learning, and doing of science and engineering:

- **Disciplinary core ideas.** By identifying and focusing on a small set of core ideas in each discipline, the framework attempts to reduce the long and often disconnected catalog of factual knowledge that students currently must learn. Core ideas in physics include energy and matter, for example, and core ideas in the life sciences include ecosystems and biological evolution. Students encounter these core ideas over the course of their school years at increasing levels of sophistication, deepening their knowledge over time.
- **Cross-cutting concepts.** The framework identifies seven cross-cutting concepts that have importance across many disciplines, such as patterns, cause and effect, and stability and change.
- **Practices.** Eight key science and engineering practices are identified, such as asking questions (for science) and defining problems (for engineering); planning and carrying out investigations; and engaging in argument from evidence.

The framework emphasizes that disciplinary knowledge and scientific practices are intertwined and must be coordinated in science and engineering education. By engaging in the practices of science and engineering, students gain new knowledge about the disciplinary core ideas and come to understand the nature of how scientific knowledge develops.

The figure below shows areas of overlap between the framework and 21st century skills. Cognitive skills—especially critical thinking, nonroutine problem solving, and constructing and evaluating evidence-based arguments—are all strongly supported in the framework, as is complex communication. In the domain of interpersonal skills, the framework provides strong support for collaboration and teamwork; a prominent theme is the importance of understanding science and engineering as a social enterprise conducted in a community, requiring well-developed skills for collaborating and



Overlap between *A Framework for K-12 Science Education* and 21st century skills.

communicating. The framework also supports adaptability, in the form of the ability and inclination to revise one's thinking or strategy in response to evidence and review by one's peers.

In terms of intrapersonal skills, the framework gives explicit support to metacognitive reasoning about one's own thinking and working processes, as well as the capacity to engage in self-directed learning about science and engineering throughout one's life-time. Support for motivation and persistence, attitudes, identity and value issues, and self-regulation is weaker or more indirect.

Deeper Learning in the Classroom: Sinking and Floating

Many elements of science education envisioned in the *Framework for K-12 Science Education*—such as the sustained development of core disciplinary ideas over time, the cultivation of reasoning and problem-solving skills at earlier ages, and attention to scientific communication—are currently uncommon in U.S. classrooms. What would a classroom that did incorporate such an approach look like?

One rich illustration comes from a 1999 study of an extended unit of science instruction with 3rd through 5th graders investigating sinking and floating. Over 10 weeks, students worked in small groups to carry out a series of investigations designed to help them understand when and why various objects will float or sink. Conceptual development in this area involves understanding mass, volume, density, and relative density—concepts that are known to be challenging for many students.

Students' hands-on investigations were carefully structured through "scaffolding," which offers prompts and other supports as students learn reasoning practices in science. Investigations were interspersed with teacher-guided whole class discussions in which students gained experience in communicating, monitoring, and critiquing their own thinking and that of their peers as they developed, tested, and evaluated theoretical explanations for the phenomena they were observing.

As students conducted their investigations, they were introduced to explicit strategies in science, including predicting and theorizing, summarizing results, and relating predictions and theories to the results obtained. Through classroom discussions and repeated opportunities to practice these strategies, students came to be able to distinguish between predictions and theories and to develop theory-based explanations of their observations. They also learned to use evidence to evaluate their theories, rejecting some and refining others.

This approach required students to develop and practice strategies from the cognitive, interpersonal, and intrapersonal domains. Students learned to apply reasoning and planning strategies for designing, conducting, and interpreting their investigations. They also became better able to monitor their thinking and to recognize when their ideas were or were not well developed or justified. And they became more comfortable with scientific discourse, learning the norms and expectations for scientific reasoning and discussion; for example, they learned not to become defensive when questioned by peers.

Systems to Support Deeper Learning

As noted above, current teaching practices in most classrooms do not encourage deeper learning of subject matter. The emergence of new standards documents in English language arts, mathematics, and science—all of which stress deeper learning and the development of cognitive competencies—offers an opportunity to shift toward practices that do facilitate deeper learning.

However, helping students develop the full range of 21st century competencies—including those in the interpersonal and intrapersonal domains—will require changes across many elements of the education system, including curriculum, assessments, and teacher education and professional development.

Curriculum. Further research and development is needed to create more specific instructional materials and strategies to develop transferable competencies. Future curricula inspired by the concept of deeper learning should integrate learning across the cognitive, interpersonal, and intrapersonal domains in whatever ways are most appropriate for the targeted learning goals. Funding agencies and policymakers should support the development and use of curriculum and instructional programs that include research-based teaching methods to support deeper learning, such as those outlined in this booklet.

Assessment. The extent to which teachers will focus on helping students develop 21st century competencies will be strongly influenced by the degree to which these competencies are included in district, state, and national assessments. Currently, educational policies and accountability systems rely on assessments that emphasize recall of facts and procedures, posing a challenge to wider teaching and learning of 21st century competencies.

Recent policy developments offer an opportunity to address this challenge. With the support of the U.S. Department of Education, two large consortia of states are developing new assessments aligned with the Common Core State Standards. If these assessments—as well as those eventually developed based on new science standards—include the facets of 21st century competencies included in the Common Core State Standards, it will provide a strong incentive for states, districts, schools, and teachers to emphasize these aspects of instruction.

Teacher education and professional development. Current approaches will require major changes if they are to support teaching that encourages deeper learning and the development of transferable knowledge and skills. Researchers have identified many needed steps, including strengthening teachers' own understanding of the subject matter they teach, their knowledge about how students learn that subject matter, and their awareness of common misconceptions students have about it. Across the disciplines, teachers will need opportunities to engage in the kinds of learning and teaching environments described in this booklet; by experiencing instruction designed to support transfer, they will be better able to design and implement such environments in their own classrooms.

Research Needs

Much research remains to be done to fill in gaps in knowledge about deeper learning and 21st century skills. Foundations and federal research agencies should support studies on teaching and learning for transfer. In particular, research is needed to:

- increase understanding of the relationships between 21st century competencies and adult outcomes;
- develop instructional design principles to guide curriculum developers and teachers in supporting learning of transferable interpersonal and intrapersonal compencies; and
- determine whether and to what extent knowledge and skills developed in one discipline or subject area can transfer to another.

About This Booklet

This booklet was prepared by the Board on Testing and Assessment (BOTA) and the Board on Science Education (BOSE) based on the report *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century* (2012), which was authored by the Committee on Defining Deeper Learning and 21st Century Skills. The study was sponsored by the Carnegie Corporation of New York, the William and Flora Hewlett Foundation, the John D. and Catherine T. MacArthur Foundation, the National Science Foundation, the Nellie Mae Education Foundation, the Pearson Foundation, the Raikes Foundation, the Susan Crown Exchange Fund, and the Stupski Foundation. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the National Research Council and do not reflect those of the sponsors.

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