A

In 1965, Robert Rosenthal and Lenore Jackson, in a now famous experiment, told a group of teachers that some of the students in their classrooms had been identified by a special Harvard test as being on the brink of rapid intellectual and academic development. Unbeknownst to the teachers, the test didn't exist at all; the students had simply been randomly labeled as having special aptitudes. By the end of the experiment, many student who had been randomly labeled as special were demonstrating higher IQs than their peers. Rosenthal and Jacobsen termed these results the "Pygmalion effect," named for the George Barnard Shaw play *Pygmalion* about a phonetics professor (Henry Higgins) who, after accepting a bet, teaches a Cockney flower girl (Eliza Doolittle) proper etiquette and diction and successfully passes her off as a lady of upper-crust London society. Rosenthal and Jacobson concluded that just as Higgins' high expectations of Eliza became a self-fulfilling prophecy, teachers' expectations of students transforms their performance.

Goodwin, Brian (2010). *Changing the odds for student success: what matters most.* Denver, CO: Mid-continent Research for Education and Learning (McREL).

B

Perhaps the most surprising aspect of … student-centered assessment is that it is motivating. Many people associate being evaluated with mild to moderate anxiety, not motivation, and research has shown that grades can be associated with decreased motivation and lower achievement (Butler & Nisan 1986; Lipnevich & Smith 2008). However, recent studies have shown that formative assessment—particularly detailed, task-specific comments on student work—can activate interest in a task (Cimpian et al. 2007) and result in better performance (Lipnevich & Smith 2008).

Andrade, Heidi, Kristen Huff and Georgia Brooke (2012). *Assessing Learning: Students and the Center*. Boston, MA: Jobs for the Future.

C

"Clear learning goals help students learn better (Seidel, Rimmele, & Prenzel, 2005). When students understand exactly what they're supposed to learn and what their work will look like when they learn it, they're better able to monitor and adjust their work, select effective strategies, and connect current work to prior learning (Black, Harrison, Lee, Marshall, & Wiliam, 2004; Moss, Brookhart, & Long, 2011). This point has been demonstrated for all age groups, from young children (Higgins, Harris, & Kuehn, 1994) through high school students (Ross & Starling,2008); and in a variety of subjects—in writing (Andrade, Du, & Mycek, 2010); mathematics (Ross, Hogaboam-Gray, & Rolheiser,2002); and social studies (Ross & Starling, 2008)."

Susan Brookhart and Connie M Moss, "Learning Targets on Parade," Ed Leadership

D

"Multiple studies have shown that teachers who teach the same subject or course at a grade level within the same school often consider drastically different criteria in assigning grades to students' performance (Cizek, Fitzgerald and Rachor 1995; McMillan, Myran & Workman 2002; Reeves 2008.)"

An Introduction to Standards-Based Grading, Marzano Research Laboratory, 2014

E

It is important to note that, in practice, competency education models can be understood as existing on a continuum. While the philosophical ideal may be for every student to advance based solely on mastery, not all schools adopting competency-based learning principles do this. Some value group learning and a sense of classroom community as much as purely individualized progression. Schools with different populations, policies, and student needs lead to distinct versions of competency education.

Making Mastery Work: Nellie Mae Education Foundation.

F

[I]n solving problems, transfer is facilitated by instruction that helps learners develop deep understanding of the structure of a problem domain and applicable solution methods, but is not supported by rote learning of solutions to specific problems or problem-solving procedures. This kind of deep, well-integrated learning develops gradually and takes time, but it can be started early: recent evidence indicates that even preschool and early elementary students can make meaningful progress in conceptual organization, reasoning, problem solving, representation, and communication in well-chosen topic areas in science, mathematics, and language arts. In addition, teaching that emphasizes the conditions for applying a body of factual or procedural knowledge also facilitates transfer.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

G

[Instructional strategies for deep learning include:]

Using multiple and varied representations of concepts and tasks, such as diagrams, numerical and mathematical representations, and simulations, combined with activities and guidance that support mapping across the varied representations.

Encouraging elaboration, questioning, and explanation—for example, prompting students who are reading a history text to think about the author's intent and/or to explain specific information and arguments as they read—either silently to themselves, or to others.

Engaging learners in challenging tasks, while also supporting them with guidance, feedback, and encouragement to reflect on their own learning processes and the status of their understanding.

Teaching with examples and cases, such as modeling step-by-step how students can carry out a procedure to solve a problem and using sets of worked examples.

Priming student motivation by connecting topics to students' personal lives and interests, engaging students in collaborative problem solving, and drawing attention to the knowledge and skills students are developing, rather than grades or scores.

Using formative assessment to: a) make learning goals clear to students; b) continuously monitor, provide feedback, and respond to students' learning progress; and c) involve students in self- and peer-assessment.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

H

Problem-solving and metacognitive competencies should be taught and assessed within a specific discipline or topic area, rather than as a stand-alone course. Teaching and learning of problem-solving and metacognitive competencies need not wait until all of the related component competencies have achieved fluency. Finally, sustained instruction and effort is necessary to develop expertise in problem solving and metacognition—there is no simple way to achieve competence without time, effort, motivation, and informative feedback.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

I

Individuals acquire a skill much more rapidly if they receive feedback about the correctness of what they have done. If incorrect, they need to know the nature of their mistake. It was demonstrated long ago that practice without feedback produces little learning (Thorndike, 1927). One of the persistent dilemmas in education is that students often spend time practicing incorrect skills with little or no feedback. Furthermore, the feedback they ultimately receive is often neither timely nor informative. Unguided practice (e.g., homework in math) can be for the less able student, practice in doing tasks incorrectly.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

J

The value of explanatory feedback has been demonstrated through research conducted in both digital and non-digital learning environments. For example, Moreno and Mayer (2005) compared two different versions of an interactive science learning game in which students traveled to different planets with different environmental conditions and were asked to design a plant that could survive in these conditions. The authors found that students who received explanatory feedback performed significantly better than students who received only corrective feedback on a test designed to measure both retention of the targeted botany concepts and transfer of these concepts to new problems of plant design based on the same general principles.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

K

Blackwell, Trzesniewski, and Dweck (2007) studied an intervention designed to change attributions among low-income minority 7th grade students in an urban school. At the beginning of the school year, the students took part in 8 workshops on brain function and study skills, over 8 weeks. Students in the experimental group were taught that the brain can get stronger when a person works on challenging tasks, while those in the control group learned only study skills. At the end of the academic year, the students in the experimental group earned significantly higher mathematics grades than those in the control group (a mean increase of 0.30 grade points), reversing the normal pattern of declining mathematics grades over the course of seventh grade. Noting that the effectiveness of interventions targeting attributions has been replicated with different student populations, Yaeger and Walton (2011) observe that these studies support the hypothesis that changes in attributions can lead to positive, selfreinforcing cycle of improvement. Students who attribute a low grade to transitory factors, such as a temporary lack of effort, rather than to a lack of general intelligence or mathematics ability, are more motivated to work harder in their classes. This leads to improved grades, which, in turn, reinforce students' view that they can succeed academically and make them less likely to attribute any low grades to factors beyond their control.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

L

Studies of metacognition have shown that people who monitor their own understanding during the learning phase of an experiment show better recall performance when their memories are tested (Nelson, 1996). Similar metacognitive strategies distinguish stronger from less competent learners. Strong learners can explain which strategies they used to solve a problem and why, while less competent students monitor their own thinking sporadically and ineffectively and offer incomplete explanations (Chi et al, 1989; Chi and VanLehn, 1991). There is ample evidence that metacognition develops over the school years; for example, older children are better than younger ones at planning for tasks they are asked to do (Karmiloff- Smith, 1979). Metacognitive skills can also be taught. For example, people can learn mental devices that help them stay on task, monitor their own progress, reflect on their strengths and weaknesses, and self-correct errors.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

M

In a recent review of the research on self-regulated learning, Wolters (2010) observes that, although there are several different models of such learning, the most prominent is that developed by Pintrich and colleagues (Pintrich 2000; 2004). In this model, learners engage in four phases of self-regulation, not necessarily in sequential order: forethought or planning (setting learning goals); monitoring (keeping track of progress in a learning activity); regulation (using, managing or changing learning strategies to achieve the learning goals; and reflection (generating new knowledge about the learning tasks or oneself as a learner). …The construct of self-regulated learning has been used to design instructional interventions that have improved academic outcomes among diverse populations of students, from early elementary school through college. These interventions have led to improvements in class grades and other measures of achievement in writing, reading, mathematics, and science (Wolters, 2010).

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

N

[I]t is worth noting that recent research on teaching and learning reveals that young children are capable of surprisingly sophisticated thinking and reasoning in science, mathematics, and other domains (National Research Council, 2012; National Research Council, 2009c). With carefully designed guidance and instruction, they can begin the process of deeper learning and development of transferable knowledge as early as preschool. As noted in chapters 4 and 5, this process takes time and extensive practice over many years, suggesting that instruction for transfer should be introduced in the earliest grades and should be sustained throughout the K–12 years as well as in postsecondary education.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

O

Research on academic motivation shows that students learn more deeply when they attribute their to performance to effort rather than to ability (Graham and Williams, 2009), when they have the goal of mastering the material rather than the goal of performing well or not performing poorly (Anderman and Wolters, 2006; Maehr and Zusho, 2009), when they expect to succeed on a learning task and value the learning task (Wigfield, Tonks, and Klauda, 2009), when they have the belief that they are capable of achieving the task at hand (Schunk and Pajares, 2009; Schunk and Zimmerman, 2006), when they believe that intelligence is changeable rather than fixed (Dweck and Master, 2009), and when they are interested in the learning task (Schiefele, 2009). There is promising evidence that these kinds of beliefs, expectancies, goals, and interests can be fostered in learners by, for example, peer modeling techniques (Schunk, Pintrich, and Meece, 2008) and through the interventions described in Chapter 4 (Yaeger and Walton, 2011).

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

P

The formative assessment concept … emphasizes the dynamic process of using assessment evidence to continually improve student learning; this is in contrast to the concept of summative assessment, which focuses on development and implementation of an instrument to measure what a student has learned up to a particular point in time (Shepard, 2005; Heritage, 2010; National Research Council, 2001). Deeper learning is enhanced when formative assessment is used to: (1) make learning goals clear to students; (2) continuously monitor, provide feedback, and respond to students' learning progress; and (3) involve students in self- and peer-assessment. These uses of formative assessment are grounded in research showing that practice is essential for deeper learning and skill development but that practice without feedback yields little learning (Thorndike, 1927; see also Chapter 4).

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

Q

Strobel and van Barneveld (2009) conducted a meta-synthesis of eight previous meta-analyses and research reviews that had compared [Problem-Based Learning] approaches with traditional, lecture-based instruction. They found that how learning goals were defined and assessed in the various individual studies affected the findings about the comparative effectiveness of the two different approaches. When the learning goal was knowledge and assessments were focused on short-term retention, traditional approaches were more effective than PBL, but when knowledge assessments focused on longer-term retention (12 weeks to 2 years following the initial instruction), PBL approaches were more effective. Furthermore, when learning goals were related to transfer or application of knowledge, PBL approaches were more effective.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

R

On the subject of when to teach, the key question is whether problem-solving strategies should be taught before or after lower-level skills are mastered. Although the research base is less developed on this question, there is converging evidence that novices can benefit from training in high-level strategies. For example, in writing instruction students can be taught how to communicate with words—by dictating to an adult, for example, or by giving an oral presentation or being allowed to write with misspelled words and improper grammar—before they have mastered lower-level skills such as spelling and punctuation (Bereiter and Scardamalia, 1987; De La Paz and Graham, 1995). In observational studies of cognitive apprenticeship, beginners successfully learn high-level skills through a process of assisted performance (Tharp and Gallimore, 1988) in which they are allowed to attempt parts of complex tasks before than have mastered basic skills. These findings suggest that higher-order thinking skills can be learned along with lower-order ones early in the instructional process.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

S

In contrast to assessments of learning that look backwards over what has been learned, assessments for learning—formative assessments—chart the road forward by diagnosing where students are relative to learning goals and by making it possible to take immediate action to close any gaps (see Sadler, 1989). As defined by Black and Wiliam (1998), formative assessment involves both understanding and immediately responding to students learning status. In other words, it involves both diagnosis and actions to accelerate student progress toward identified goals. Formative assessment is sometimes referred to as "dynamic assessment," to reflect this active process. … Actions could include: teachers asking questions to probe, diagnose, and respond to student understanding; teachers asking students to explain and elaborate their thinking; teachers providing feedback to help students transform their misconceptions and transition to more sophisticated understanding; and teachers analyzing student work and using results to plan and deliver appropriate next steps, for example, an alternate learning activity for students who evidence particular difficulties or misconceptions.

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

T

A hallmark of formative assessment is its emphasis on student efficacy, as students are encouraged to be responsible for their learning and the classroom is turned into a learning community (Gardner, 2006; Harlen, 2006). To assume that responsibility, students must clearly understand what learning is expected of them, including its nature and quality. Students receive feedback that helps them to understand and master performance gaps, and they are involved in assessing and responding to their own work and that of their peers (see also Heritage, 2010).

National Research Council. (2012). *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century.* Committee on Defining Deeper Learning and 21st Century Skills, James W. Pellegrino and Margaret L. Hilton, Editors. Board on Testing and Assessment and Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

U

In choosing an appropriate reporting form based on purpose, educators must seek a balance between detail and practicality. A standards-based report card should present a comprehensive picture of students' academic strengths and challenges. It also might include space to record students' self evaluations, dpeneding on the defined purpose. But regardless of the form, a standards-based report card should be compact and understandable and should not require inordinate time for teachers to prepare or for parents to interpret (Linn & Gronlund, 2000).
…[R]eport cards consisting of multiple pages with long lists of skills and multiple categories of information are not only terribly time consuming for teachers to complete, they typically overwhelm parents with information they do not know how to use. More often than not, such report cards simply overwhelm parents."

Guskey, Thomas and Jane M. Baily (2010). *Developing Standards-Based Report Cards*. Thousand Oaks, CA: Corwin Press.

V

Because of concerns about student motivation, self-esteem, and the social consequences of grading and reporting, most teachers base their grading procedures on some combination of [product, process, and progress] learning goals (Brookhart, 1993; Frary, Cross & Weber, 1993; Friedman and Manley, 1992; Nava & Loyd, 1992; Stiggins, Frisbie & Griswold, 1989). In many cases, they combine elements of product, process, and progress into a single grade or mark. Evidence indicates that teachers also vary the goals they consider from student to students, taking into account individual circumstances (Burstuck et al., 1996; Natriello, Riehl & Pallas, 1994; Truong & Friedman, 1996). Although they do this in an effort to be fair, the result is a "hodgepodge grade" that includes components of achievement, effort and improvement (Brookhart, 1991; Cross & Frary, 1996). Interpreting the grade or report card thus becomes extraordinarily difficult, not only for parents but also for administrators, community members, and even the students themselves (Friedman & Frisbie, 1995; Waltman & Frisbie, 1994).

Guskey, Thomas and Jane M. Baily (2010). *Developing Standards-Based Report Cards*. Thousand Oaks, CA: Corwin Press.

W

The use of frequent formative assessment helps make students' thinking visible to themselves, their peers, and their teacher. This provides feedback that can guide modification and refinement in thinking. Given the goal of learning with understanding, assessments must tap understanding rather than merely the ability to repeat facts or perform isolated skills.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

X

Superficial coverage of all topics in a subject area must be replaced with in-depth coverage of fewer topics that allows key concepts in that discipline to be understood. The goal of coverage need not be abandoned entirely, of course. But there must be a sufficient number of cases of in-depth study to allow students to grasp the defining concepts in specific domains within a discipline. Moreover, in-depth study in a domain often requires that ideas be carried beyond a single school year before students can make the transition from informal to formal ideas. This will require active coordination of the curriculum across school years.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

Y

Transfer is affected by the degree to which people learn with understanding rather than merely memorize sets of facts or follow a fixed set of procedures… Learners, especially in school settings, are often faced with tasks that do not have apparent meaning or logic (Klausmeier, 1985). It can be difficult for them to learn with understanding at the start; they may need to take time to explore underlying concepts and to generate connections to other information they possess. Attempts to cover too many topics too quickly may hinder learning and subsequent transfer because students (a) learn only isolated sets of facts that are not organized and connected or (b) are introduced to organizing principles that they cannot grasp because they lack enough specific knowledge to make them meaningful.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

Z

Learners of all ages are more motivated when they can see the usefulness of what they are learning and when they can use that information to do something that has an impact on others— especially their local community (McCombs, 1996; Pintrich and Schunk, 1996). Sixth graders in an inner-city school were asked to explain the highlights of their previous year in fifth grade to an anonymous interviewer, who asked them to describe anything that made them feel proud, successful, or creative (Barron et al., 1998). Students frequently mentioned projects that had strong social consequences, such as tutoring younger children, learning to make presentations to outside audiences, designing blueprints for playhouses that were to be built by professionals and then donated to preschool programs, and learning to work effectively in groups. Many of the activities mentioned by the students had involved a great deal of hard work on their part: for example, they had had to learn about geometry and architecture in order to get the chance to create blueprints for the playhouses, and they had had to explain their blueprints to a group of outside experts who held them to very high standards.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

BB

One aspect of previous knowledge that is extremely important for understanding learning is cultural practices that support learners' prior knowledge. Effective teaching supports positive transfer by actively identifying the relevant knowledge and strengths that students bring to a learning situation and building on them. Transfer from school to everyday environments is the ultimate purpose of school-based learning. An analysis of everyday environments provides opportunities to rethink school practices in order to bring them into alignment with the requirements of everyday environments. But it is important to avoid instruction that is overly dependent on context. Helping learners choose, adapt, and invent tools for solving problems is one way to facilitate transfer while also encouraging flexibility. Finally, a metacognitive approach to teaching can increase transfer by helping students learn about themselves as learners in the context of acquiring content knowledge. One characteristic of experts is an ability to monitor and regulate their own understanding in ways that allows them to keep learning adaptive expertise: this is an important model for students to emulate.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

AA

While time on task is necessary for learning, it is not sufficient for effective learning. Time spent learning for understanding has different consequences for transfer than time spent simply memorizing facts or procedures from textbooks or lectures. In order for learners to gain insight into their learning and their understanding, frequent feedback is critical: students need to monitor their learning and actively evaluate their strategies and their current levels of understanding. The context in which one learns is also important for promoting transfer. Knowledge that is taught in only a single context is less likely to support flexible transfer than knowledge that is taught in multiple contexts. With multiple contexts, students are more likely to abstract the relevant features of concepts and develop a more flexible representation of knowledge. The use of well-chosen contrasting cases can help students learn the conditions under which new knowledge is applicable. Abstract representations of problems can also facilitate transfer. Transfer between tasks is related to the degree to which they share common elements, although the concept of elements must be defined cognitively. In assessing learning, the key is increased speed of learning the concepts underlying the new material, rather than early performance attempts in a new subject domain. All new learning involves transfer. Previous knowledge can help or hinder the understanding of new information. For example, knowledge of everyday counting-based arithmetic can make it difficult to deal with rational numbers; assumptions based on everyday physical experiences (e.g., walking upright on a seemingly flat earth) can make it difficult for learners to understand concepts in astronomy and physics and so forth. Teachers can help students change their original conceptions by helping students make their thinking visible so that misconceptions can be corrected and so that students can be encouraged to think beyond the specific problem or to think about variations on the problem.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

CC

Many models of curriculum design seem to produce knowledge and skills that are disconnected rather than organized into coherent wholes. The National Research Council (1990:4) notes that "To the Romans, a curriculum was a rutted course that guided the path of two-wheeled chariots." This rutted path metaphor is an appropriate description of the curriculum for many school subjects:

> Vast numbers of learning objectives, each associated with pedagogical strategies, serve as mile posts along the trail mapped by texts from kindergarten to twelfth grade. . . . Problems are solved not by observing and responding to the natural landscape through which the mathematics curriculum passes, but by mastering time-tested routines, conveniently placed along the path (National Research Council, 1990:4).

An alternative to a " rutted path" curriculum is one of "learning the landscape" (Greeno, 1991). In this metaphor, learning is analogous to learning to live in an environment: learning your way around, learning what resources are available, and learning how to use those resources in conducting your activities productively and enjoyably (Greeno, 1991:175). The progressive formalization framework discussed above is consistent with this metaphor. Knowing where one is in a landscape requires a network of connections that link one's present location to the larger space. Traditional curricula often fail to help students "learn their way around" a discipline. The curricula include the familiar scope and sequence charts that specify procedural objectives to be mastered by students at each grade: though an individual objective might be reasonable, it is not seen as part of a larger network. Yet it is the network, the connections among objectives, that is important. This is the kind of knowledge that characterizes expertise. Stress on isolated parts can train students in a series of routines without educating them to understand an overall picture that will ensure the development of integrated knowledge structures and information about conditions of applicability.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press

DD

Connections to experts outside of school can also have a positive influence on in-school learning because they provide opportunities for students to interact with parents and other people who take an interest in what students are doing. It can be very motivating both to students and teachers to have opportunities to share their work with others. Opportunities to prepare for these events helps teachers raise standards because the consequences go beyond mere scores on a test (e.g., Brown and Campione, 1994, 1996; Cognition and Technology Group at Vanderbilt, in press b). The idea of outside audiences who present challenges (complete with deadlines) has been incorporated into a number of instructional programs (e.g., Cognition and Technology Group at Vanderbilt, 1997; Wiske, 1997). Working to prepare for outsiders provides motivation that helps teachers maintain student interest. In addition, teachers and students develop a better sense of community as they prepare to face a common challenge. Students are also motivated to prepare for outside audiences who do not come to the classroom but will see their projects.

Bransford, John D., Ann L. Brown and Rodney R. Cocking, editors (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington, D.C.: National Academies Press