From the National Academy of Sciences:

Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century

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We define "deeper learning" as the process through which an individual becomes capable of taking what was learned in one situation and applying it to new situations (i.e., transfer). Through deeper learning (which often involves shared learning and interactions with others in a community), the individual develops expertise in a particular domain of knowledge and/or performance (see Chapters 4 and 5). The product of deeper learning is transferable knowledge, including content knowledge in a domain and knowledge of how, why, and when to apply this knowledge to answer questions and solve problems.

We refer to this blend of both knowledge and skills as "21st century competencies." The competencies are structured around fundamental principles of the content area and their relationships rather than disparate, superficial facts or procedures. It is the way in which the individual and community structures and organizes the intertwined knowledge and skills—rather than the separate facts or procedures per se—that supports transfer. While other types of learning may allow an individual to recall facts, concepts, or procedures, deeper learning allows the individual to transfer what was learned to solve new problems.

Research has identified features of instruction that are likely to substantially support deeper learning and development of 21st century competencies within a topic area or discipline. For example, we now know that transfer is supported when learners understand the general principles underlying their original learning and

the transfer situation or problem involves the same general principles—a finding reflected in the new Common Core State Standards and the NRC science framework, which highlight learning of general principles. Similarly, in 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.

• [All relevant agencies] should support the development of curriculum and instructional programs that include research-based teaching methods, such as:

- 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.

For instruction focused on development of problem-solving and metacognitive competencies, the committee recommends:

- Designers and developers of curriculum, instruction, and assessment in problem solving and metacognition should use modeling and feedback techniques that highlight the processes of thinking rather than focusing exclusively on the products of thinking. 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 are necessary to develop expertise in problem solving and metacognition; there is no simple way to achieve competence without time, effort, motivation, and informative feedback.

Components of Deeper Learning

Researchers have characterized the suite of knowledge and abilities that are used in the process of deeper learning in various ways. For example, when Anderson et al. (2001) updated Bloom's 1956 taxonomy of learning objectives, they included three types of knowledge and skills: (1) knowledge (e.g., facts and concepts); (2) skills (e.g., procedures and strategies); and (3) attitudes (e.g., beliefs). In Chapter 2, we proposed that knowledge and skills can be divided into three broad domains of competence: cognitive, intrapersonal, and interpersonal.

Mayer (2011a) suggested that deeper learning involves developing an interconnected network of five types of knowledge:

- Facts, statements about the characteristics or relationships of elements
- in the universe;
- Concepts, which are categories, schemas, models, or principals;
- Procedures, or step-by-step processes;
- Strategies, general methods; and

- Beliefs about one's own learning.

Earlier in this chapter, we noted that mentally organizing knowledge helps an individual to quickly identify and retrieve the relevant knowledge when trying to solve a novel problem (i.e., when trying to transfer the knowledge). In light of these research findings, Mayer (2010) proposed that the way in which a learner organizes these five types of knowledge influences whether the knowledge leads to deeper learning and transfer. For example, factual knowledge is more likely to transfer if it is integrated, rather than existing as isolated bits of information, and conceptual knowledge is more likely to transfer if it is mentally organized around schemas, models, or general principles. As the research on expertise and the power law of practice would indicate, procedures that have been practiced until they become automatic and embedded within long-term memory are more readily transferred to new problems than those that require much thought and effort.
In addition, specific cognitive and metacognitive strategies (discussed later in this chapter) promote transfer. Finally, development of transferable 21st century skills is more likely if the learner has productive beliefs about his or her ability to learn and about the value of learning—a topic we return to later, in the section on the intrapersonal domain.

Table 4-2 outlines the cognitive processing of the five types of integrated knowledge and dispositions that, working closely together, support deeper learning and transfer.

TABLE 4-2 What Is Transferable Knowledge?

Type of Knowledge Format or Cognitive Processing

- Factual Integrated, rather than separate facts
- Conceptual Schemas, models, principles
- Procedures Automated, rather than effortful
- Strategies Specific cognitive and metacognitive strategies
- Beliefs Productive beliefs about learning

SOURCE: Adapted from Mayer (2010).

Deeper learning involves coordinating all five types of knowledge. The learner acquires an interconnected network of specific facts, automates procedures, refines schemas and mental models, and refines cognitive and metacognitive strategies, while at the same time developing productive beliefs about learning. Through this process, the learner develops transferable knowledge, which encompasses not only the facts and procedures that support retention but also the concepts, strategies, and beliefs needed for success in transfer tasks. We view these concepts, thinking strategies, and beliefs as 21st century skills.

This proposed model of transferable knowledge reflects the research on development of expertise, which, as noted above, has distinguished differences in the knowledge of experts and novices in domains such as physics, chess, and medicine (see Table 4-3). Novices tend to store facts as isolated units, whereas experts store them in an interconnected network. Novices tend to create categories based on surface features, whereas experts create categories based in whereas experts create categories based in structural features. Novices need to expend conscious effort in applying procedures, whereas experts have automated basic procedures, thereby freeing them of the need to expend conscious effort in applying them. Novices tend to use general problem-solving strategies such as means-ends analysis, which require a backward strategy starting from the goal, whereas experts tend to use specific problem-solving strategies tailored to specific kinds of problems in a domain, which involve a forward strategy starting from what is given. Finally, novices may hold unproductive beliefs, such as the idea that their performance depends on ability, whereas experts may hold productive beliefs, such as the idea that if they try hard enough they can solve the problem. In short, analysis of learning outcomes in terms of five types of knowledge has proven helpful in addressing the question of what expert problem solvers know that novice problem solvers do not know.

TABLE 4-3 Expert-Novice Differences on Five Kinds of Knowledge

Knowledge	Novices	Experts
Facts	fragmented	integrated
Concepts	surface	structural
Procedures	effortful	automated
Strategies	general	specific
Beliefs	unproductive	productive

SOURCE: Adapted from Mayer (2010).