

Bransford, J., Stevens, R., Schwartz, D., Meltzoff, A., Pea, R., Roschelle, J., Vye, N., Kuhl, P., Bell, P., Barron, B., Reeves, B., & Sabelli, N. (2006). Learning theories and education: Toward a decade of synergy. In P. Alexander & P. Winne (Eds.), *Handbook of educational psychology* (2nd ed., pp. 209-244). Mahwah, NJ: Erlbaum.

• 10 •

LEARNING THEORIES AND EDUCATION: TOWARD A DECADE OF SYNERGY

*John Bransford
Reed Stevens
Dan Schwartz
Andy Meltzoff
Roy Pea
Jeremy Roschelle*

*Nancy Vye
Pat Kuhl
Philip Bell
Brigid Barron
Byron Reeves
Nora Sabelli*

The LIFE Center: The University of Washington, Stanford University, & SRI, Inc.

LEARNING THEORIES AND EDUCATION: TOWARD A DECADE OF SYNERGY

Our goal is to provide an overview of important aspects of human learning that are particularly relevant to educators. Doing so represents an exciting but difficult challenge because human learning is a highly complex topic. Different theories have emerged as researchers have focused on different kinds of learning. Some have focused on the acquisition of skills such as learning to type, write and read (e.g., Anderson, 1981; Bryan & Harter, 1897; LaBerge & Samuels, 1974; National Research Council [NRC], 2000). Others have focused on learning with understanding and its effects on schema formation and transfer (e.g., Anderson & Pearson, 1984; Judd, 1908; NRC, 2000; Wertheimer, 1959). Still others study the emergence of new ideas through interactions with other people and through "bumping up against the world" (e.g., Carey, 2000; Gopnik, Meltzoff, & Kuhl, 1999; Karmiloff-Smith & Inhelder, 1974; Papert, 1980; Vygotsky, 1978).

Learning theorists have also explored different settings for learning—including preschool, school, experimental

laboratory, informal gathering spots, and everyday home and workplace settings—and they have used a variety of measurements of learning (e.g., neurobiological, behavioral, ethnographic). Furthermore, learning theorists work at time scales that range from milliseconds of processing time to life-span and even intergenerational learning (e.g., Lemke, 2001; Newell, Liu, & Mayer-Kress, 2001). Making sense of these different perspectives, and giving each their just due, is a challenging task.

In addressing this challenge, we have the good fortune of being able to build on the previous edition of the *Handbook of Educational Psychology* (Calfee & Berliner, 1996). For example, Calfee and Berliner (Chapter 1) provide an excellent introduction to the origins and goals of educational psychology. Mayer and Wittrock (Chapter 3) discuss research on transfer—a key concept for educators. Greeno, Collins, and Resnick (Chapter 2) examine important traditions of thought that have been used to analyze the processes of human learning—traditions such as the rationalist, empiricist, and sociohistorical. Greeno et al. contrast the different ways in which these traditions have viewed cognition and learning, and how each tradition has contributed to the design of educational

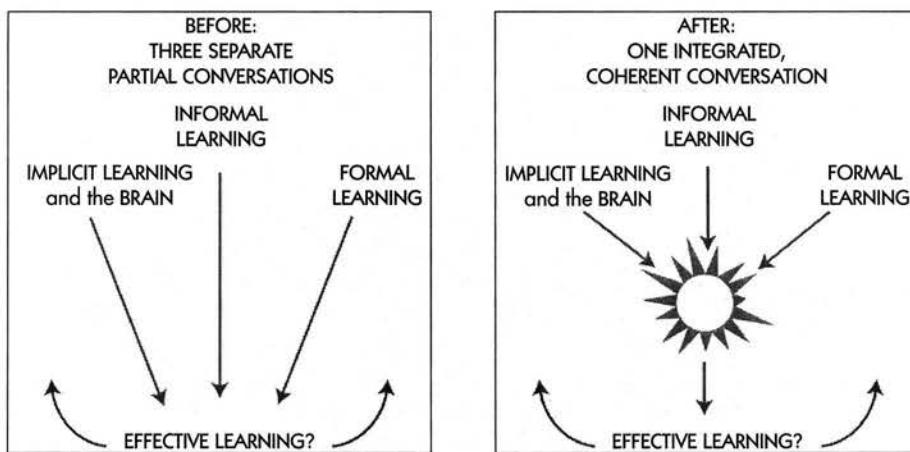


FIGURE 10.1. Toward an integrated sciences of learning.

practices. Greeno et al. also discuss major changes in how learning research has been conducted during the past 30 years—changes that involve moving from “laboratory only” studies to research conducted in complex environments such as classrooms, schools and districts (e.g., Brown, 1992; Cognition and Technology Group at Vanderbilt [CTGV], 2000; Collins, 1992; Design-Basel Research Collective [DBRC], 2003; Linn, Davis, & Bell, 2004; Resnick, 1987), plus learning “in the wild” in everyday settings (e.g., see Bransford & Heldmeyer, 1983; Lave, 1988; Resnick, 1987; Stevens, 2000a). These changes are fundamental to the discussion that appears later.

As indicated by the title of this chapter, our goal is to write with an eye toward the coming decade, which we believe will be a “decade for synergy.” We do not attempt an exhaustive review of all learning research that is potentially relevant to education. Instead, we build on discussions by Greeno et al. and focus on several key traditions of thinking and research that have the potential to mutually influence one another in ways that can transform how we think about the sciences of learning, and how future educators and scientists are trained. We believe that the timing is right for targeted efforts toward synergy to become an explicit goal of educational researchers.

The three major areas of research that we explore include (1) implicit learning and the brain, (2) informal learning, and (3) designs for formal learning and beyond. As illustrated in Fig. 10.1A, these three areas have tended to operate relatively independently of one another. Researchers in each of these areas have attempted to apply their thinking and findings directly to education, and often the links between theory and “well grounded implications for practice” have been tenuous at best.

The goal of integrating insights from these strands in order to create transformative theories of learning is

illustrated in Fig. 10.1B. The fundamental reason for pursuing this goal rests on the assumption that successful efforts to understand and propel human learning require a simultaneous emphasis on informal and formal learning environments, and on the implicit ways in which people learn in whatever situations they find themselves.

In the remainder of this chapter we explore examples of research from each of the three strands depicted in Fig. 10.1. We then suggest ways in which learning theorists of the future might draw on these traditions in order to create a more robust understanding of learning that can inform the design of learning environments that allow all students to succeed in the fast changing world of the 21st century (e.g., Darling-Hammond & Bransford, 2005; Vaill, 1996).

IMPLICIT LEARNING AND THE BRAIN

The first strand illustrated in Fig. 10.1 is implicit learning and the brain. *Implicit learning* refers to information that is acquired effortlessly and sometimes without conscious recollection of the learned information or having acquired it (Berry, 1997; Graf & Schacter, 1985; Reber, 1967; Seger, 1994; Stadler & Frensch, 1998). There are many types of implicit learning, but a common process may underlie all forms—the rapid, effortless, and untutored detection of patterns of covariation among events in the world in the absence of conscious, reflective strategies to learn (Reber, 1993). Our interest in implicit learning reflects the view that (a) it is implicated in many types of learning that take place in both informal and formal educational settings, (b) it encompasses skill learning, which plays a vital role in many other types of learning, and (c) it plays a substantive role in learning about language and people across the life span.

Implicit learning occurs in many domains. For example, it influences social attitudes and stereotypes regarding gender and race (Greenwald et al., 2002), visual pattern learning (DeSchepper & Treisman, 1996), motor response time tasks (Nissen & Bullemer, 1987), syntactic language learning (Reber, 1976), early speech learning (Goodsitt, Morgan, & Kuhl, 1993; Kuhl, 2004; Saffran, 2002), and young children's imitative learning of the tools/artifacts behaviors, customs, and rituals of their culture (Meltzoff, 1988b; Rogoff, Paradise, Mejía Arauz, Correa-Chávez, & Angelillo, 2003; Tomasello, 1999).

Moreover, a substantial portion of learning from media and technology is implicit. Only a minority of research about the effects of media and technology test purposive effects of messages, for example, formal classroom learning from instructional media (Mayer, Fennell, Lindsay, & Cambell, 2004) or the ability of television news to teach citizens about how candidates stand on political issues (Krosnick & Branon, 1993; Schleuder, McCombs, & Wanta, 1991). More commonly, media research examines effects that are indirect, involve automatic attentional processes, and are often beyond the conscious awareness of those processing the information. This includes the ability of media to determine the perceived importance of political issues (Iyengar & Kinder, 1987; Spiro & McCombs, 2004); learning about the appropriateness of social behavior in interpersonal relationships (Glascock, 2001; Larson, 2001); the influence of media on perceptions of social reality, for example, what people learn about the prevalence of crime (Shanahan & Morgan, 1999; Sparks & Ogles, 1990); learning from persuasive consumer messages that occurs subliminally (Petty, Priester, & Briñol, 2002; Trappey, 1996) or through frequent and implicit associations between people, places, and appeals (Chang, 2002; Invernizzi, Falomir, Manuel, Muñoz, & Mugny, 2003); learning about the personal qualities of prominent figures in politics and government based on how messages are framed (Benoit & Hansen, 2004; Iyengar & Simon, 1993) and on the visual structure (e.g., cuts, camera angles, use of motion sequences) used to present information (Mutz & Reeves, in press); and learning to control complex media such as computer games (Berry & Broadbent, 1988).

Across both live, face-to-face interactions and mediated interactions, the common conclusion is that people can learn patterned regularities without intending to do so and sometimes without being able to describe the patterns they have learned (though this is not always the case; see Buchner, Erdfelder, Steffens, & Martensen, 1997). In some instances, it can be shown that "trying to learn" patterns of covariation through explicit instruction actually impedes learning, underscoring the idea that implicit and explicit forms of learning are different (Howard

& Howard, 2001). Studies also suggest that it may not be the material *per se* that distinguishes implicit from explicit learning, but how the material is presented to learners and encoded (Poldrack et al., 2001). Implicit learning has educational and even evolutionary value inasmuch as it enables organisms to adapt to new environments simply by being in them and observing and interacting with the people and objects encountered there (Howard & Howard, 2001). (We explore the idea of what it means to "be in an environment" in more detail in a later section, "Looking Toward the Future.")

The label *implicit learning* that we are using in this chapter is not meant to be an operationally defined category with necessary and sufficient conditions for inclusion and exclusion. We focus on two domains that are prototypical cases of implicit learning and which provide much food for thought—language learning (Kuhl, 2004; Kuhl, Tsao, & Liu, 2003; Saffran, 2003; Newport & Aslin, 2004) and learning about people, sometimes called "social cognition" (e.g., Flavell & Miller, 1998; Meltzoff & Decety, 2003; Ochsner & Lieberman, 2001; Taylor, 1996), with heavy emphasis on the former case. Our lifelong learning about language and people begins before kindergarten, and in some cases important foundations are established in the first year of life. In these domains parents are the first "teachers" and much is absorbed through spontaneous and unstructured play (Meltzoff, 2005).

For purposes of this chapter we explore three key hypotheses: (a) implicit learning plays an important role across the life span, starting very early in life; (b) research on language has discovered principles of learning that emphasize the importance of patterned variation and the brain's coding of these patterns, and these findings may illuminate other cognitive and social domains; and (c) principles uncovered through research in language and social learning raise questions about K-12 education and "oversimplified" curriculum design. We say more about this later. First we explore whether, how, and why studies of the brain and early learning inform broader issues in the science of learning and are important for educators to know.

What Does Brain Science Add to the Study of Learning?

Research that attempts to find correlations between brain and behavior has a long history, but work in this area has skyrocketed in the past several decades. The 1990s were dubbed "The Decade of the Brain" and produced advances in neuroscience techniques. Modern neuroscience can reveal learning in an alive, awake brain, detecting the impact of experiential learning *before it can*

be observed in behavior. This is a change from studies in the 70s and 80s in which most knowledge of the brain came from the study of brains at autopsy. The study of a live brain "at work" is new, and is now being done in infants and children as well as adults.

The potential of new neural measures of mental activity were quickly noted by educators and policymakers. In 1996, the Education Commission of the States and the Dana Foundation held a conference entitled *Bridging the Gap Between Neuroscience and Education*, which brought together leaders in the two fields (Denver, Colorado, July 26–28, 1996). The conference sparked a heated debate. The gap between the neuron and the chalkboard was acknowledged as substantial—many agreed it was perhaps a "bridge too far" at that point in time—and scholarly articles and books resulted (e.g., Bruer, 1997, 1999; NRC, 2000; Gopnik et al., 1999).

Although excitement about advances in brain research is evident, it is useful for educators to pose a probing question: What, precisely, are the advantages of knowing which brain regions are activated over time and how they are associated with behavioral changes? Will brain studies *really* alter what we do in our schools?

The answer to that question is not straightforward (Bruer, 1997, 1999; NRC, 2000). Brain studies link neural underpinnings to behavioral function; they will help us understand learning. Altering what we do in classrooms is a step beyond this and will take much more than brain science. However, there are new research topics, for example, the effects of bilingual exposure on language, cognition, and mathematical learning, that should affect educational policy. That said, it is also important to understand limitations. Few, if any, neuroscientists think that brain science will, for example, generate a new science curriculum or tell us how to structure a high school student's day to optimize learning. Research in the future needs to combine educators and neuroscientists to study learning across settings—and this will take a great deal of collaborative work. We discuss this more in the section on the future.

Neurobiological studies do, however, provide crucial knowledge that cannot be obtained through behavioral studies, and this provides at least three justifications for adding cognitive neuroscience to our arsenal of tools for developing a new science of learning. First, a mature science of learning will involve understanding not only *when* learning occurs, but also understanding *how* and *why* it occurs. The how and why of learning are exposed if we discover its neural underpinnings and identify the internal mechanisms that govern learning across ages and settings. Second, neural learning often precedes behav-

ior (Tremblay, Kraus, & McGee, 1998), offering a chance for scientists and educators to reflect on what it means to "know" and "learn." Third, behaviors that appear similar may involve different neural mechanisms that have different causes and consequences. Better categorization of behaviors, according to neural function instead of the appearance of behavioral similarity, should allow the educational strategies and policies that affect learning to be usefully grouped in ways not obvious absent the study of brain function.

Learning theories of the future will embody both neural and behavioral aspects of learning, and both behavioral and brain-imaging methods are used by researchers engaged in Strand 1 research ("Implicit learning and the brain"). It is the premise of Strand 1 research that neither brain nor behavior trumps the other; the approaches are thoroughly complementary and not competitive. In the following discussion, we provide a few targeted examples that illustrate research on brain that raises important questions about understanding and optimizing learning.

Learning to Interpret Brain Data

Introducing neuroscience to learning science is challenging because, for some, biological constraints on common behaviors must be studied at an unfamiliar level of analysis. That's not where the complexity stops, however. Practically, researchers must also learn new methods that go with the new theories. There are a number of ways to measure brain activities. Examples include event-related potentials (ERPs), which track changes in the electrically evoked potentials measured on the surface of the scalp; fMRI (which tracks hemodynamic changes in the brain); and MEG (which tracks magnetic field changes in the brain over time). Each of these measures can be used to study learning.

It is especially important to note that valid inferences about brain processes often require a series of converging experiments rather than only one or two. In the language domain, learning of the basic building blocks—the consonants and vowels that make up words—is of interest because it develops early in infancy, it is resistant to change in adulthood (for example, people find it difficult to rid themselves of accents), and it reflects a "critical period" for learning. A thorough understanding of this process requires a programmatic research effort. In the case of speech perception, for example, the literature has progressed rapidly over the last 10 years (see Kuhl, 2000, for review). Learning induced changes in the brain involve biological processes that have many complicated and interacting pathways of regulation just like other biological

processes. This is another reason why the “bridge” from neuroscience to education is difficult to build. Nevertheless, there are important conjectures from brain research that are relevant to educators’ thinking, and selected examples are provided later.

Some Key Brain Findings and Their Importance

The Brain at Birth. It is a common misconception that each individual’s brain is entirely formed at birth. This is not the case. Instead, experiences during development have powerful effects on the physical development of the brain itself (e.g., Greenough, Juraska, & Volkmar, 1979). One intriguing aspect of the human brain’s development is the process of “pruning.” In young children, the brain “overproduces” synapses that are then either maintained or removed as a result of experience. The process of synaptic overproduction takes place at different rates in different parts of the brain (Huttenlocher & Dabholkar, 1997). For example, in the primary visual cortex, the peak in synaptic density occurs early in life, whereas the process is more protracted in brain regions associated with higher cognitive functions. Neuroscientists speculate that pruning may provide an explanation for a range of developmental changes that occur in people; for example, in the area of language development, it has been found that very young children have the capacity to discriminate among more phonemes than they do as adults (Kuhl, 2004; Werker and Tees, 1984). It is tempting to think that synaptic overproduction accounts for children’s early precocities, and that experience with a specific language—where some phonemes are not used—results in the maintenance of connections for those phonemes represented in the language, and loss of connections for those not represented. However, we are far from a conclusion on this claim; the underlying physiological mechanisms that account for our changing abilities to discriminate phonemes outside our native language are not well understood, although proposals do exist for future investigations (McClelland, 2001; McClelland, et al., 2002; Zhang, Kuhl, Imada, Kotani, & Tokura 2005).

Although synaptic development and subsequent “pruning” have received much attention in the press (perhaps because the reduction of synapses over time is counterintuitive), it is only one example among many that demonstrate changes in the brain during development. The next decade of research in neuroscience will focus on the relationship between behavioral development and brain development, further expanding the field of cognitive neuroscience. One thing has been established without a doubt—experiences helps sculpt an individual’s

brain. Brain development is not a product of nature or nurture exclusively, but is a complex interaction of both.

Assumptions About Critical Periods for Learning. For educators, the idea of rapid brain organization during the early years of life is important but can also lead to serious misconceptions (Bruer, 1999). For example, people often question whether children who spend their early years in understimulating environments will have fewer chances for future learning and development. The popular literature is filled with discussions of “critical periods” for learning, and the assumption persists that the ability to learn certain kinds of information shuts down if the critical period is missed, with detrimental effects on learning forever. Assumptions such as these sometimes cause teachers and parents to underestimate the abilities of students whose early years seemed less rich and more chaotic than others who come to school.

Brain research shows that the timing of critical periods differs significantly depending on whether one is discussing the visual, auditory, or language systems. Even within different systems, there is emerging evidence that the brain is much more plastic than heretofore assumed, and that the idea of rigid “critical periods” does not hold.

New studies by Kuhl and colleagues explored potential mechanisms underlying critical periods in early language development (e.g., Kuhl, 2004; Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005). She introduced the concept of a *neural commitment* for learning language patterns. These recent neuropsychological and brain imaging studies suggest that language acquisition involves the development of attentional networks that focus on and code specific properties of the speech signals heard in early infancy, resulting in neural tissue that is dedicated to the analysis of these learned patterns. Early in development, learners commit the brain’s neural networks to patterns that reflect natural language input. Kuhl’s claim is that early learning both supports and constrains future learning. Early neural commitment to the phonetic units of a specific language supports the learning of more complex patterns, such as words, of that language. However, neural commitment to learned patterns also constrains future learning because neural networks dedicated to native-language patterns are incompatible with non-native patterns, and in fact may interfere with their analysis (Iverson et al., 2003). The concept of neural commitment is linked to the long-standing issue of a “critical” or “sensitive” period for language acquisition. If the initial coding of native-language patterns interferes with the learning of new patterns (such as those of a foreign language), because they do not conform to the established “mental filter,” then early learning can limit later learning. The “critical

period" thus depends on experience as much as time and is a *process*. Thus both maturation and learning determine the critical period. Maturation may "open" the period during which learning can occur, but learning itself may play a powerful role in "closing" the period (Gopnik et al., 1999; Kuhl, 2004).

The general point is that learning can produce neural commitment to the properties of the stimuli we see and hear. Exposure to a specific data set alters the brain by establishing neural connections that "commit" the brain to processing information in an ideal way for that particular input (e.g., one's first language but not for subsequent languages). Neural commitment functions as a "filter" that affects future processing (Kuhl, 1991; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Näätänen et al., 1997). This results in highly efficient processing of learned material (Zhang et al., 2005). The most well studied example concerning the development of neural commitment is language, but it is only one of many.

Broadening this discussion, the neural commitment concept can be thought of as a neural instantiation of important dimensions of "expertise" in any domain. Expertise in many areas may reflect these kinds of filters on experience—filters that focus attention, and structure perception, thought, and emotions so that we work more efficiently. This focused efficiency simultaneously frees up our attention and energies to think creatively in other domains, and may also, in certain circumstances, limit our ability to think in novel ways within the area of expertise (e.g., Gopnik & Meltzoff, 1997). For example, learning algebraic principles or mastering the scientific method changes our filters (our concepts and theories), leading us to perceive the world in a new way. This learning alters the brain's future processing of information. A fundamental question is how the brain can form neural commitments while also maximizing our ability to stay open for adaptive change. This is an issue that receives more attention later when we discuss adaptive expertise.

New Learning and Existing Neural Commitments: Neuroplasticity. In adulthood, second language learners have to work with committed brains to develop new networks. As years of research attest, babies are better at learning new languages than we are! Infants' systems are not yet thoroughly committed and are therefore capable of developing more than one "mental filter." For example, in a recent study, Kuhl and colleagues tested whether American 9-month-old infants who had never before heard Mandarin Chinese could learn the phonemes of Mandarin by listening to Chinese graduate students play and read to them in Mandarin Chinese (Kuhl, Tsao, & Liu, 2003). The study was designed to test whether infants can learn from short-term exposure to a natural foreign language.

In the experiment, 9-month-old American infants listened to four native speakers of Mandarin during 12 sessions in which they read books and played with toys. After the sessions, infants were tested with a Mandarin phonetic contrast that does not occur in English to see whether exposure to the foreign language had reversed the usual decline in infants' foreign-language speech perception. The results showed that infants learned during these targeted, live sessions, compared with a control group that heard only English. Indeed the American infants performed at a level that was statistically equivalent to infants tested in Taiwan who had been listening to Mandarin for 11 months. The study shows how readily young infants learn from natural language exposure at this age, apparently running computational algorithms on natural language that they hear delivered in a playful and social way (Kuhl et al., 2003).

Kuhl et al. (2003) designed a test to examine the degree to which infant language learning depends on live human interaction. A new group of infants saw and heard the same Mandarin speakers on a television screen (or heard them over loudspeakers). The auditory cues available to the infants were identical in the televised and live settings, as was the use of "motherese." If simple auditory exposure to language prompts learning, the presence of a live human being would not be essential. However, the infants' Mandarin discrimination scores after exposure to televised or audio-taped speakers were no greater than those of the control infants who had heard only English. These infants simply did not learn language in the TV or auditory-alone conditions. Further experiments clearly are needed to determine the factors contributing to the advantage provided by live/social interaction versus television or audiotapes. It may be due to the young age of the children, the domain of learning (language), or the limitations of the television display used in this experiment (e.g., it was not interactive TV). The strong interpretation of the findings is that infants may need a social tutor to learn natural language (and evolution may have prepared this), but clearly more work is needed before this strong claim can be accepted (Kuhl, 2003).

One reason social environments may enhance learning is that real social interactions provide more complex and variable training that highlights the critical parameters necessary in mastering a task. In this sense, the "complexities" of live interactions may be good for young infants, at least in certain circumstances. There are hints from other literature as well that initial learning that takes into account the full complexity of situations may make initial learning a little more difficult but ultimately improve transfer and generalization (e.g., Bransford & Nitsch, 1978; Simon & Bjork, 2002). There is also some fledgling evidence in the cognitive literature

that "hybrid models" of instruction might enhance initial learning and subsequent transfer (e.g., Bransford & Nitsch, 1978). Appropriate social interactions may provide hybrid conditions because they present complexity in manageable proportions. There is much work to be done to understand these processes in more detail.

Even with social interaction, adults do not learn everything with ease, and language again provides a well-worked-out example. For instance, classic experiments show that even with extensive training, adults often do not learn foreign-language contrasts (see Strange, 1995, for review). Recent experiments, however, show that mimicking the features of infant-directed speech may help adult learners and those with language impairments. In studies of Japanese adults, McClelland and his colleagues (McClelland, 2001; McClelland et al., 2002), showed that learning increased when the /r/ and /l/ sounds were acoustically "stretched" to highlight the differences between the two instances. Tallal et al. (1996) and Merzenich et al. (1996) showed the same advantage when "stretched" acoustic instances were used to teach children with dyslexia to discriminate speech sounds. What is interesting about these cases is that infant-directed speech also exaggerates, literally "stretches," the acoustic features of native language when addressing infants; this is a universal feature of "motherese" across cultures (Kuhl et al., 1997). And infants whose mothers stretch the acoustic features of speech show better speech discrimination abilities (Liu, Kuhl, & Tsao, 2003). In other words, both first and second language learners are assisted by acoustically exaggerated speech. Kuhl (2000) hypothesized that the early highlighting of the acoustic features of speech helps establish the brain's initial mapping for speech; in adulthood, this stretching may also assist adults in going beyond their first language's neural maps (McClelland et al., 2002; Kuhl, 2000 for discussion). This is a key example where work concerning first learning in infancy can be extrapolated and used to inform formal learning and instruction in adults. The importance of understanding how to help people move beyond their current "comfort zones" of efficiency is also emphasized in a later section ("Designs for Formal Learning and Beyond").

Other features are also proving important to adult "re-training" with foreign-language stimuli. Early experiments on training utilized one talker's speech sounds. Training was highly successful, but there was virtually no generalization to novel cases by new talkers or new speech contexts (McClelland, 2001; McClelland, et al., 2002). Others have shown that learners do best with more complexity, and that optimal learning is produced when many talkers' sounds are presented during training (Pisoni et al., 1994). The newer research with adults again takes a lesson from infant learning; adults addressing infants and children vary

speech to resemble multiple talkers, which appears to be helpful to language learning (Burnham et al., 2002; Kuhl et al., 1997; Liu et al., 2003).

Children's Implicit Learning From Other People: The Case of Imitative Learning

Other studies by brain and developmental scientists are also relevant to sciences of learning. One example that has increasingly attracted the attention of developmental psychologists, neuroscientists, evolutionary biologists, and those interested in robotics comes from children's learning from watching other people. This is a skill that is important both for the transmission of culture from parents to children and in peer-group learning. The topic of imitative learning has undergone a revolution in the past decade, as studies have revealed the ubiquitous nature of imitation among humans across the life span (e.g., Meltzoff, 2005; Meltzoff & Prinz, 2002). Research now shows that human beings are the most imitative creatures on the planet. Humans imitate from birth (Meltzoff & Moore, 1977), and the young child's capacity to learn from imitation outstrips that found in other primates such as chimpanzees and gorillas (Povinelli, Reaux, Theall, & Giambrone, 2000; Tomasello & Call, 1997; Whiten, 2002).

Recently, the importance of imitative learning has been given a boost by the discovery of "mirror neurons" that are activated whether a subject sees an action performed by another or performs the action themselves (e.g., Hurley & Chater, 2005; Meltzoff & Prinz, 2002). There are mirror neurons in the premotor cortex of the monkey (e.g., Rizzolatti, Fadiga, Fogassi, & Gallese, 2002; Rizzolatti, Fadiga, Gallese, & Fogassi, 1996), but monkeys do not imitate. So imitative learning involves more than the presence of mirror neurons, and neuroscientists are trying to determine the special, perhaps uniquely human abilities that support our proclivity for learning by observing others in the culture (see Meltzoff & Decety, 2003, for a review).

One possibility is that even a simple act of imitation is connected with perspective-taking and therefore is more of a social and collaborative activity than it first appears (Meltzoff, 2005). Consider that the model or teacher and child rarely see the world from the same perspective. The child sees her own body and own actions from a "first person" perspective; but we see others from a "third-person" perspective. Imitation requires that the child watch the adult and be able to "transform" what the adult does across differences in points of view, size, and sensory modality. Even a simple act of imitation requires facility in identifying with others and being able to "take their perspective."

This capacity for perspective taking may be fundamental to humans and important to a wide range of learning activities. Indeed, some have argued that the close neural coupling of self and other that undergirds imitation may also be implicated in such other distinctively human traits as social collaboration (Rogoff, 2003), the preservation of cultural practices involving implicit teaching and learning across generations (Meltzoff, 1988b, 2005; Tomasello, 1999), and empathy for others, where empathy is viewed as a kind of emotional perspective taking that requires us to stand in another's shoes (e.g., Jackson, Meltzoff, & Decety, 2005).

Regardless of these theoretical views, ample research shows that young children learn a great deal about people and cultural artifacts through imitation, and children are influenced not just by their parents, but also by their peers and what they see on television. For example, one study showed that toddlers learn from and imitate their peers in day-care centers (Hanna & Meltzoff, 1993). Another showed that preschoolers learn and remember novel actions they see on television (Meltzoff, 1988a). In that study, 2-year-olds watched an adult perform a novel action on TV. The children were not allowed to play with the object, but returned to the lab after a 1-day delay, and then were presented with the novel object for the first time. The results showed they duplicated from memory the specific act that they had seen on TV one day earlier.

Current research is exploring the conditions under which infants and young children can or cannot learn from TV. Recall that the Kuhl experiments (noted earlier) suggested that infants under 1 year old did not learn foreign speech sounds purely from watching TV. We want to know whether the difference between the Kuhl (no learning from TV) and Meltzoff (learning from TV) findings are due to a difference in age of the subjects (10-month-olds vs. 2-year-olds), the type of material being learned (speech vs. human actions on objects), or motivational/interactive factors—to name just a few possible variables. The outcome of this line of research is likely to be informative not only for theory, but for the booming market of media toys and educational materials for infants and preschoolers.

INFORMAL LEARNING

The second strand of research illustrated in Fig. 10.1 involves a focus on informal learning. The term *informal learning* has been used to refer to at least two distinct but overlapping areas of study, and we draw an initial distinction to make clear our use of the phrase within this chapter. Some researchers use the phrase to refer to learning that happens in designed, nonschool public settings such as museums, zoos, and after-school clubs. Others

use the phrase *informal learning* to focus attention on the largely emergent occasions of learning that occur in homes, on playgrounds, among peers, and in other situations where a designed and planned educational agenda is not authoritatively sustained over time. For our current purposes, we will focus on the latter sense of informal learning, but later in the section we will revisit the general issue of how to define the domain of interest for informal learning research.

If we begin by looking outside of traditional schooling and focus our attention on children rather than adults, we note that 79 percent of a child's waking activities, during the school-age years, are spent in nonschool pursuits—interacting with family and friends, playing games, consuming commercial media, and so on (NRC, 2000). If we extend this calculation to the human life span, the portion of time spent outside of school, and therefore a potential source of informal learning, would be over 90 percent. Turning to adults specifically, we note that a great deal of what an adult learns in a lifetime is not "covered" in school (e.g., raising a child, saving and investing money wisely). And even with regard to what is "covered," it remains an open question to ask in what ways school-based learning substantively transfers to nonschool life in both occupational and every day contexts.

Informal learning is understudied when compared with learning in schools. Nevertheless, it is noteworthy that even the limited research that exists shows a strong divergence of views concerning the nature, effects, and value of informal learning (e.g., Smith, diSessa, & Roschelle, 1993). On one hand, informal learning has been championed as a romantic alternative to schools, where productive proto-forms of disciplinary knowledge and other forms of productive knowledge develop with minimal effort. A contrasting perspective argues that informal learning leads people to form naïve and misconceived ideas at odds with disciplinary knowledge (e.g., Driver, Guesne, & Tiberghien; 1985; McCloskey, 1983), and that these everyday "naïve" ideas need to be overcome to allow normative knowledge to develop. Another pair of contrasting perspectives on informal learning concerns the quality of the thinking and practices in which informal situations engage people. On one hand, some view informal learning situations as wellsprings of new knowledge and cultural production, especially among young people (e.g., Gee, 2003a, 2003b). On the other hand, some view informal situations as characterized by a lack of thinking and the consumption of a degraded popular culture (Healy, 1991). These diverging views, along with the sheer amount of time spent at informal learning, argue for more research to clarify these questions.

Despite these differences in views about informal learning, we feel that the learning tradition described in

this section is essential to “the decade of synthesis” that was discussed earlier (see Fig. 10.1). With this goal in mind, we must remind ourselves that achieving a genuine synthesis of distinct traditions on learning is a formidable challenge that may be facilitated by articulating the history and principles that animate each tradition (see Astuti, Solomon, & Carey, 2004). With this in place, we will be in a better position to unearth conceptual collisions that can sharpen, challenge, and extend the respective traditions, as we do in the final section. Articulating these principles also creates opportunities to forge new transdisciplinary connections, in terms of new approaches both to research on learning and to new educational projects informed by such a synthesis.¹

History of Informal Learning and Everyday Cognition Research

In this section we offer a thumbnail sketch of important researchers, projects, and institutions where informal learning research has been conducted. As we noted, the research tradition on informal learning has its origins mostly outside of mainstream educational psychology. Ethnographic work in anthropology established the perspective in the first half of the 20th century, by showing that while many non-Western societies lack formal schooling they do not lack meaningful, everyday learning. This poses the problem of how people learn without teaching, curricula, and schooling as conventionally understood in Western industrialized societies. As recently argued by McDermott (2001), an informal learning perspective is clearly present in Margaret Mead's *Coming of Age in Samoa* (1928) and is developed further in Mead's continuing work with Gregory Bateson. As McDermott (2001) notes,

Mead did not write much about learning theory, at least not directly; but it would be easy to reshape her ethnographies into accounts of what the people studied were learning from each other about how to behave, be it about adolescence in Samoa; gender among the Arapesh, awayness among the Balinese. Her version of the social actor, that is, the unit of analysis in her ethnographies, was in constant need for guidance from others. (p. 855)

A second line of work that provides theoretical roots for an informal learning perspective comes out of the

sociological ethnography of Howard Becker and his colleagues. Beginning in the late 1950s and finding full expression in the 1960s and early 1970s, Becker and colleagues explored questions of how and what people learned, mostly in occupations, but also in clearly informal situations for which no curricula or schooling exists. Characteristic of the latter was Becker's influential article *Becoming a Marihuana User* (1953). Becker argued against an exclusively skill-based notion of learning that has been characteristic of both behaviorism (physical skills) and cognitivism (mental skills). Becker's critical addition was to show that learning also involved the development of particular *meanings* for a skill, which were learned among other community members:

Marihuana-produced sensations are not automatically or necessarily pleasurable. The taste for such experience is a socially acquired one, not different in kind from acquired tastes for oysters or dry martinis. The user feels dizzy, thirsty; his scalp tingles; he misjudges time and distances; and so on. Are these things pleasurable? He isn't sure. (p. 239)

Becker argues that becoming a marihuana user requires that one learn to experience the sensations of smoking as pleasurable, through the appropriation of a set of socially transmitted *meanings* of experience. What's important about this argument is that it focused on a type of learning that is often understood in terms of biophysical effects and the skills needed to produce these effects. Becker's analysis clearly shows that these skills are necessary but hardly sufficient; equally critical are the socially transmitted, gradually appropriated meanings for the experience.² Becker's view of how people acquire these meanings foreshadows the view that has come to be known as *guided participation* (Rogoff, Matusov, & White, 1996) and resonates with the focus on guidance in Margaret Mead's early anthropological studies, thus tracing a pair of interrelated concepts—*guiding* and *participating*—across nearly a century of studies of informal learning.

Becker and colleagues' studies of how people learn in occupations—what has been described as “the becoming a...” genre (Katz, 2001, p. 457)—have also been important for a number of reasons. First, these studies also brought significant attention to the peer-maintained informal cultures that arose among students in formal institutions—what might be called the informal properties of formal settings. Second, these were among the

¹An alternative approach is when one tradition seeks to co-opt or swallow another whole. A good example of this approach, which we do not recommend, is well represented by Vera and Simon's (1993) claim that studies of situated action can be easily subsumed by a cognitivist symbol system approach.

²Bruner suggests that attention to the appropriation of meaning was intended to be part of the original agenda for the “cognitive revolution” but was shelved in the pursuit of a pure machine cognitivist paradigm (Bruner, 1990).

earliest studies to locate the development of identity as a dimension of learning (e.g., Becker & Carper, 1956). As we will describe later, the concept of identity has become central to understanding informal learning. When one is learning outside of school, it is as much about who one wants *to be* as what one demonstrably comes *to know*. Becker's studies of how people learned outside of formal schooling also led Becker to be among the first to explicitly seek to compare the different conditions under which learning in and out of schools takes place. Becker's provocation was that school, despite its labeled purpose, is often a "lousy place to learn anything in." Becker argued that it was the specific structural properties of how school is *typically* organized (cf. Tyack & Tobin, 1984, on the "grammar of schooling") when compared to other learning situations, such as on-the-job training, that made it lousy.

At about the same time Becker and his colleagues were conducting their studies on informal learning, a movement among some psychologists began to establish a "comparative psychology of cognition" (Cole & Bruner, 1971). In practice, this programmatic goal led to many studies of informal learning, both within non-Western cultures and within nonschooled activities in Western societies. The two most prominent contributors to this line of work at the time were collaborators Michael Cole and Sylvia Scribner.³ For these psychologists, suspicions about the limited validity of psychological tests for understanding people's thinking led them to pursue a culturally sensitive methodology for studying cognition and learning (Cole, 1996). Because Anglo-American psychology confined itself rather rigidly to testing-based laboratory approaches at the time, Scribner and Cole looked to the work of Russian scientists on human learning and cognition for inspiration (Leont'ev, 1978; Luria, 1976; Vygotsky, 1962, 1978, 1987).

One foundational study that influenced the comparative tradition was *The Logic of Nonstandard English* by sociolinguist William Labov (1969). This study sought to challenge what Labov called a deprivation view and what has come to known as *the deficit hypothesis*: "[This view] rests on the assumption that a community under conditions of poverty [e.g., most ethnic minority communities] . . . is a disorganized community, and this disorganization expresses itself in various forms of deficit" (Cole & Bruner, 1971, p. 867).

Labov's specific focus was a purported deficit in speech practices of African-Americans attributed to them

by prominent educational psychologists of the time.⁴ What Labov's study showed was two-fold: (1) that although different, African-American speech practices obeyed just as strict a "logic" as middle-class European-American speech, and (2) that seemingly small changes in the context of eliciting speech, used to make research generalization about categories of people, can have a decisive impact on the kinds of performances displayed by research subjects *to research scientists*. To make this point, Labov presented the case of an African-American boy named Leon who when interviewed at school by a skilled African-American interviewer was taciturn and "nonverbal" in response to questions. Upon review of the recordings made, Labov and his colleagues decided to use this data as "a test of [their] own knowledge of the sociolinguistic factors which control speech" (Labov, 1972, p. 160). When the same interviewer spoke again with Leon, the interview was held in Leon's room at home, with Leon's best friend and a bag of potato chips as part of the conversational scene. In comparison with the first interview at school, there was a "striking difference in the volume and style of speech" (Labov, 1969). In this situation, Leon had a lot to say, competed for the floor, and spoke as much to his friend as to the interviewer—all strong contrasts with the first interview situation.

What links all of the studies that form a foundation of an informal learning tradition is an insistence on including *fieldwork* to document naturally occurring activities among its data collection strategies. A well-elaborated program of research that combined fieldwork and experimentation was led by Sylvia Scribner and is exemplified in Scribner's studies of learning and cognition among dairy workers (Scribner, 1997a, 1997b; Scribner & Fahrmeir, 1982). A number of important features of Scribner's work are relevant to our discussion here. First, Scribner substantially challenged the limited role that mainstream psychology gave to fieldwork. For mainstream psychologists, the only role that the field held for studies of cognition and learning was the generation of hypotheses that would then be tested in the laboratory.⁵ Scribner argued that controlled experimentation—in the form of posed simulation tasks closely based on field observations—was valuable in exploring specific hypotheses about human cognition and activity, but that these claims still needed to be tested *again* in various fields of naturally occurring activity. A second feature of Scribner's studies was that she showed how physical and mental labor were both elements of what people learned as part of everyday work

³For a partial history of the LCHC (1972–1984) from Cole's perspective, see <http://lchc.ucsd.edu/Histarch/lchc.history.html>.

⁴Labov quotes representative passages from Deutsch, Jensen, and Bereiter.

⁵This conceptualization of the role of fieldwork remains common in contemporary accounts of research methods.

and that demands of the work environment substantially explained the distribution of these types of labor in daily work practice. Finally, Scribner showed the limited relevance of certain school-based mathematical learning to mathematical tasks that arose in dairy work, thus presenting an early challenge to the view that "formal" learning transferred to "informal" tasks.

In addition to the research on informal learning associated with Cole & Scribner's research laboratories (see Cole, Engeström, & Vasquez, 1997, for an overview; also, Tobach, Falmagne, Parlee, Martin, & Kapelman, 1997), the early 1980s brought work by anthropologists, sociolinguists, and a small subset of psychologists into closer conversation, both theoretically and methodologically. Jean Lave, whose research in the 1970s involved an explicit comparison of formal and informal mathematics among Liberian apprentice tailors, went on to lead a project (The Adult Math Project) in the 1980s studying how adults in everyday situations used mathematics. This project culminated in her influential 1988 book *Cognition in Practice*. Lave's research took aim at the cognitivist concept of transfer and argued against the view of everyday cognition as degraded or lesser form of cognition when compared with its formal counterparts. This is a move Scribner also made in her studies of dairy workers and has been made forcefully by Mike Rose in a series of recent studies looking at the complex learning and cognition involved in blue-collar work (Rose, 2004).

Among the other important researchers taking up questions of informal learning in the early 1980s were Geoffrey Saxe (1982), Catherine Snow (1982), Shirley Brice Heath (1983), Barbara Rogoff (Rogoff & Lave, 1984), and Carraher, Carraher, and Schliemann (1985). Regardless of disciplinary background, studies by all of these scholars employed fieldwork methods, often along with posed tasks, to explore the relations between informal learning and learning in schools.

Though this is just a thumbnail sketch, unforgivably partial, of informal learning research, it should serve to orient readers to some relevant landmarks in this terrain. And, although the number of studies of informal learning pale in comparison to those of formal learning, a range of insights and principles nonetheless distinguish informal learning research. These we describe next.

Principles and Basic Contributions of an Informal Learning Perspective

In this section, we describe some of the animating principles and contributions that have been made by studies of informal learning as they have sought to provide an account of the distinctive processes, conditions and

outcomes of learning in human activities outside of formally prepared educational designs.

Clarification of the Role and Meaning of Context in Learning. Two related senses of *context* have been important in informal learning and everyday cognition research. The first sense of *context* has been a setting-based one, with settings such as "work," "play," "school," and "street" forming the bases for comparative analysis. A second sense of context is more analytically fine-grained and is often embedded within the first, with comparisons being made across activities, forms of participation, and types of interaction in the respective settings. Many researchers have explored, for example, how learning in homes and learning at school compare. Findings from these studies sort out in two basic ways, depending on the forms of knowledge and practice under consideration and depending on the research participants. On one hand, researchers sometimes find alignments between different activity contexts being compared. This is the case in Ochs, Taylor, Rudolph, & Smith's (1992) well-known study, which found that the dinner-table conversations of middle-class families served as settings for children to develop theory-making discourse practices common in some arenas of academic discourse practice. More typically, however, informal learning studies have found that the practices and knowledge of compared settings differ in important and consequential ways, thus leading to the view that what is important or necessary to learn in each setting differs accordingly.

An early influential study of this kind was Philips' (1983) study that compared the participation structures and speech practices of Native American children in school and in their cultural community contexts. Philips found that the adults in the respective contexts—the elders of the community and the teachers at school—differed in their expectations for children's speech and that these differences manifested themselves at the level of how turns at talk were allocated. This had the effect of leading the children's teachers, of a different cultural background, to misunderstand their abilities. Other informal learning studies that have compared contexts for learning include Saxe (1982), Carraher, Carraher, and Schliemann (1985), Heath (1983, 2001), deAbreu (1995), Hall and Stevens (1995), and Stevens (2000a).

Although studies of informal learning have been used to cast a critical eye on the traditional practices of schooling and to provide ideas for formulating alternative educational practices, the focal attention to context as a theoretical construct among informal learning researchers has led to a more general reinterpretation of school as a context, namely that *it is one*. As one interpreter of Lave's argument put it, many view school as "a neutral ground

apart from the real world, in which things learned are later *applied in* the real world. . . . Lave's argument is rather that all learning is learning *in situ*, and that schools constitute a very specific situation for learning with their own cultural, historical, political, and economic interests; interests obscured by the premise that schools are *as situational*" (Suchman, 1995, p. 72; for related views, see Eckert, 1989; Willis, 1981).

New Ways to Understand How People Learn. Nearly all studies of informal learning highlight that learning happens without most of the apparatus of schooling such as intentional teaching, designed and sequenced curricula, and regular individualized knowledge assessments. This leads researchers to try to describe the means, pathways, and practices by which learning happens in nonschool settings. Many of the alternative formulations of how people learn play off concepts of apprenticeship (Lave & Wenger, 1991; Rogoff et al., 1996). Specific constructs include Lave & Wenger's idea of *legitimate peripheral participation*, which highlights the practices by which newcomers are gradually enculturated into participation in existing "communities of practice" and Rogoff et al.'s related notion of *intent participation*, in which learning is described as happening "through keen observation and listening, in anticipation of participation . . . [children] observe and listen with intent concentration and initiative, and their collaborative participation is expected when they are ready to help in shared endeavors" (Rogoff, 2003, p. 176). Understanding learning in this way attends to how individuals can learn without explicit teaching but through participation in a community's ongoing activities.

New Theoretical Constructs for What Changes When People Learn. In the machine cognitive era, psychologists typically viewed learning changes in terms of individual mental contents (e.g., concepts) or mental processes (e.g., reasoning strategies). Informal learning researchers have described other, though not necessarily incompatible, dimensions of change when people learn. For example, a number of informal learning researchers have described learning in terms of changing forms of *participation* in ongoing cultural activities (Engeström, Brown, Christopher & Gregory, 1997; Lave & Wenger, 1991; Rogoff et al., 1996). We noted earlier that other researchers have highlighted that learning involves changes in people's *identities*—who they understand themselves to be and who others position them to be (Becker, 1953; Holland, Lachicotte, Skinner, & Cain, 1998; Lave & Wenger, 1991; Nasir, 2002; Wenger, 1999). Others have highlighted that learning, even in activities typically understood as academic or theoretical, involves changes in *tool-mediated, embodied skills* (Goodwin,

2000; Rose, 2004; Stevens & Hall, 1997, 1998; Wertsch, 1998). Though no single definition of learning unites studies of informal learning, Hutchins' definition of learning as "adaptive reorganization in a complex system" (Hutchins, 1995) is a reasonable placeholder for a working consensus view and one that links it to other contemporary views on "adaptive expertise" described in the next section.

Promising Directions for Informal Learning Research

As documented in the previous sections, research on informal learning and everyday cognition has progressed in fits and starts. Yet, just as the past two decades of research on learning in school environments have reshaped our understanding of human cognition and influenced educational practice (NRC, 2000, 2005), there is reason to hope that sustained research focused on *learning in informal settings* can be similarly transformative in the coming decades. In the remainder of this section we describe some general contemporary issues worth pursuing.

Within-Context Studies. A good proportion of research in the everyday cognition and informal learning traditions documents adult activities within specific settings. In terms of settings where this research has been conducted, these studies range from what is conventionally viewed as "lowbrow" work (Beach, 1993; Rose, 2004; Scribner, 1997b) to "highbrow" professional work (Hall & Stevens, 1995; Hall, Stevens, and Torralba, 2002; Hutchins, 1995; Jacoby & Gonzales, 1991; Latour, 1995; Ochs et al., 1992; Stevens & Hall, 1998). Taken together, these studies expose the limitations of assumed hierarchies (i.e., low to high or concrete to abstract) and entrenched binary distinctions such as "mind/body," "expert/novice," and "theoretical/practical." A similarly extensive program of research on children's informal activities may hold the possibility of additional theoretical reframings of how we understand the basic categories of children's activities and development, such as, for example, the unexamined distinction between "play" and "work." At a more basic level, these studies can help us understand how the demands, problems, constraints, and affordances of particular contexts organize stable forms of learning and development within these contexts for children and how children organize their own learning in contexts. Even in anthropology, ethnographic description "of children and their agency" has been "sparse" (Das, 1998).

We have just described the ways that within-context studies have challenged a variety of common distinctions. Perhaps the most limiting distinction of all, and one in need of reformulation, is the distinction between "informal" and "formal." As we described earlier, this distinction serves as an entry point into our discussion of different

traditions for studying learning and marks some rough differences between self-organized, emergent learning and learning occasioned by organized instruction and designed curricula. Nevertheless, the distinction is limiting because, as argued from many perspectives, a setting-based notion of context makes too many assumptions about the homogeneity of settings (i.e., that all activities in places called "schools" or "homes" are similar) and the homogeneity of experience within these settings for individual learners (Becker, 1972; Rogoff, Paradise, Mejia Arauz, Correa-Chávez, & Angelillo, 2003; Schegloff, 1992). For example, emergent learning may be as present in some school contexts as in out-of-school ones (Stevens, 2000a, 2000b). If we set aside the firm distinction between "informal" and "formal," the foundational issue becomes *the structuring properties of contexts for learning and development*, with the very nature of what constitutes a "context" remaining an open theoretical question (Goodwin, 1992).

One particular direction for further research is to identify and study *exceptional informal contexts* in which young people are in control of advancing their own learning, with the goal of understanding *how people advance their own learning* by assembling and coordinating heterogeneous resources (Barron, 2004, in review; Becker, 1972; Crowley & Jacobs, 2002; Lave & Wenger, 1991). As with any field-based scientific discipline, we need to better understand the distribution of "ecological niches" in which children are most actively engaged, and study how the problems that emerge in these nonschool settings make new knowledge necessary and certain kinds of thinking and action adaptive. We also have strong reason to believe that descriptions of mean tendencies are insufficient, because distributions of resources and practices vary widely by gender, ethnicity, and socioeconomic status, an issue of importance for translating findings from basic research to the educational goal of developing more equitable learning environments.

Across-Context Studies. Reframing the core theoretical issue in terms of contexts for learning and development, rather than in terms of an "informal/formal" distinction, points to one of the most understudied topics in this area, namely, *how people learn and develop as they make transitions across contexts*. Questions about transitions need to be studied along temporal dimensions that are both synchronic (i.e., as children move from school to home on a particular day⁶) and diachronic (i.e., as people move from postsecondary "training" to occupational work) dimensions. For example, research following this

perspective would include how children and their families manage transitions across home, school, and peer activities. A suggestive finding taking on this perspective comes from Gutierrez, who challenges a mismatch view of why children of poor backgrounds fare less well in school than their peers of middle-class backgrounds. The mismatch view holds that there is a close match between what children learn in middle-class homes and what they are asked to learn in schools, and a mismatch between what poor children learn at home and what they are asked to learn in schools. An alternative view comes from studying children moving across the contexts of school and home. This is the view that school reorganizes home life for *all* families, but that middle-class homes have greater resources (e.g., to hire tutors or parents with time to "help" with homework)⁷ to respond to how school reorganizes home life (Gutierrez, 2005).

A better understanding of what people bring to, take from, and adapt across different contexts may also have important implications for how educators design the next generation of designed learning environments. To understand and facilitate extended meaningful subject-matter learning, we need to better understand the specific resources that young people bring to school from their informal activities as well as how school-based knowledge is utilized to further informal learning. One fruitful model for how to do this is represented in studies and educational initiatives organized around the concept of young people's "funds of knowledge" (González, Moll, & Amanti, 2005; see also Heath, 1983; Lee, 1995).

DESIGNS FOR FORMAL LEARNING AND BEYOND

The third strand of research illustrated in Fig. 10.1 involves the use of knowledge about learning to create designs for formal learning and beyond (where "beyond" includes ideas for school redesign and connections to informal learning activities), and to study the effects of these designs to further inform theoretical development. Most research in educational psychology falls within this strand of research. Several chapters in the original *Handbook of Educational Psychology* (Calfee & Berliner, 1996) provide particularly relevant information about designs for formal education (see especially Greeno, Collins, & Resnick, 1996; Mayer & Wittrock, 1996). Since publication of the *Handbook*, several additional research summaries have become available. These include *Being Fluent with Information Technology*

⁶A similar perspective may be fruitful for studying children's learning within school across the different subjects that they experience during the school day (Stevens, Wineburg, Herrenkohl, & Bell, in press).

⁷See McDermott, Goldman & Varenne (1984).

(1999), *How People Learn* (NRC, 2000), *Knowing What Students Know* (NRC, 2001), *Learning and Understanding* (NRC, 2002), *Learning and Instruction: A SERP Research Agenda* (NRC, 2003), *Internet Environments for Science Education* (Linn, Davis, & Bell, 2004), *How Students Learn* (NRC, 2005), and *Preparing Teachers for a Changing World* (Darling-Hammond & Bransford, 2005).

It is impossible to do justice to all the work in this area. We organize discussion around three design questions for creating effective learning environments (e.g., Wiggins & McTighe, 1997):

1. What do we want students to know and be able to do (and what configurations of attitudes, skills, and knowledge structures support these goals)?
2. How will we know if we are successful? For example, what kinds of assessments do we need?
3. What is known about the processes involved in helping students meet our learning goals?

Clarifying Learning Goals and the Processes That Support Them

During the past decade, progress has been made in defining standards for proficiency in areas such as reading, science, mathematics, and history. A number of publications and Web sites are available to help educators translate general national standards into particular ones at the state or local level, and to also link standards to curricula (e.g., National Council of Teachers of Mathematics [NCTM], 1989, 1995, 2000; NRC, 1996; Project Achieve at www.achieve.org).

Efforts to define standards represent an important advance in U.S. and international education. From a learning perspective, it is also important to understand the social and cognitive processes that support the kinds of competencies that we want students to develop. Studies of expertise provide valuable information about these competencies.

Lessons from Studies of Expertise

Researchers have explored the nature of the skills and knowledge that underlie expert performance (e.g., Ackerman, 2003; Alexander, 2003; Chi, Glaser, & Farr, 1988; Hatano & Osuro, 2003; Lajoie, 2003; NRC, 2000; Sternberg, 2003). This research is relevant to education *not* because we need to make everyone a world-class expert in some field. Instead, the research is important for understanding ways that knowledge, skills, attitudes, and thinking strategies combine to support effective

performances in a wide variety of domains. For example, Rose's *The Mind at Work* (2004) illustrates characteristics of everyday expertise that fit closely with characteristics of "academic" expertise.

Expertise and Noticing. One important finding from the expertise literature is that experts notice features of problems and situations that may escape the attention of novices (e.g., see Chase & Simon, 1973; Chi, Glaser & Rees, 1982; deGroot, 1965). They therefore "start problem solving at a higher place" than novices (deGroot, 1965).

The fact that expertise affects noticing has a number of important educational implications. One is that merely showing novice students videos of experts doing things does not guarantee that the novices notice all the relevant features (e.g., Michael, Klee, Bransford, & Warren, 1993). Second, the idea that what we learn depends in part on what we notice highlights the need to clarify what it means to "be in" a situation. For example, peoples' sensitivity to noticing can affect their "sense of disequilibrium" (Feuerstein, Rand & Hoffman, 1979; Piaget, 1964), which in turn can trigger "fault driven" learning strategies (e.g., Van Lehn, 1990). If people fail to notice subtle examples that create disequilibria, they do not experience the need to attempt to change their views.

Expertise and Knowledge Organization. Research on expertise also provides important information about knowledge organization. Experts' knowledge is much more than a list of disconnected facts about their disciplines. Instead, their knowledge is connected and organized around important ideas of their disciplines, and it includes information about conditions of applicability of key concepts and procedures. The latter information helps experts know when, why, and how aspects of their vast repertoire of knowledge and skills are relevant in any particular situation (see Chi et al., 1988; NRC, 2000, Chapter 2).

Courses are often organized in ways that fail to develop the kinds of organized knowledge structures that support activities such as effective reasoning and problem solving. For example, texts often present lists of topics and facts in a manner that has been described as "a mile wide and an inch deep" (e.g., NRC, 2000). This is very different from focusing on the "enduring ideas of a discipline" (Bruner, 1960). Wiggins and McTighe (1997) argue that the knowledge to be taught should be prioritized into categories that range from "enduring ideas of the discipline" to "important things to know and be able to do" to "ideas worth mentioning." Thinking through these issues and coming up with a set of "enduring connected ideas" is an extremely important aspect of educational

design (e.g., Bransford, Vye, Bateman, Brophy, & Roselli 2004; Diller, Roselli, & Martin, 2004; Harris, Bransford & Brophy, 2002).

Expertise and Teaching. Information about relationship between expert knowledge and teaching abilities is especially important for thinking about instruction. Teachers need considerable content knowledge in order to answer a wide range of content questions that arise from the problems that students confront. Teachers who don't understand their subject matter will often have difficulty answering these questions. A potential downside to a great deal of knowledge about subject matter is that this information has become so tacit and intuitive that experts lose sight of what it was like to be a novice. Nathan, Koedinger, and Alibali (2001) use the term *expert blind spots* to indicate that experts are often blind to the fact that much of their subject matter knowledge has moved from explicit to tacit and hence can easily be skipped over in instruction (Brophy, 2001). Shulman (1987) explains that effective teachers need to develop "pedagogical content knowledge" that goes well beyond the content knowledge of a discipline (see also Hestenes, 1987). It includes an understanding of how novices typically struggle as they attempt to master a domain and an understanding of strategies for helping them learn (see Grossman, Schoenfeld, & Lee, 2005).

Adaptive Expertise

Many researchers suggest that it is important to differentiate "routine expertise" from "adaptive expertise" (e.g., Alexander, 2003; Hatano & Inagaki, 1986; Hatano & Osuro, 2003). Both routine experts and adaptive experts continue to learn throughout their lifetimes. Routine expertise involves the development of a core set of competencies that can be applied throughout one's life with greater and greater efficiency. In contrast, adaptive expertise involves the willingness and ability to change core competencies and continually expand the breadth and depth of one's expertise. This often requires people to leave their current "comfort zones" and venture into areas where they must function as "intelligent novices" who often struggle initially in order to learn new things (e.g., Brown, Bransford, Ferrara, & Campione, 1983; Bruer, 1993). It seems likely that most people function as routine experts in some parts of their lives and as adaptive experts in others.

This restructuring of core ideas, beliefs, and competencies can be a highly emotional experience (e.g., Gopnik

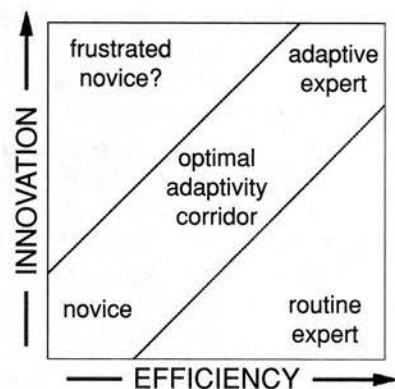


FIGURE 10.2. Two dimensions of adaptive expertise.

& Meltzoff, 1997) and may reduce people's efficiency in the short run but make them more flexible in the long run. For example, a tennis player may take lessons and be told that he is gripping the racket incorrectly. In order to reach a new level of performance, he will have to unlearn that behavior and take the time to learn a new one. In short, he'll have to get worse in order to get better in the long run, what some psychologists have called "regression in the service of development" (Bever, 1982). In the leadership literature, similar regressions are often referred to as the "implementation dip" that frequently accompanies attempts to move away from old efficiencies and try something new (Fullan, 2001, 2003). Issues of learning at the level of company strategies for product development also require such adaptive expertise for survival, as Christensen (1997) writes about in *The Innovators' Dilemma*⁸ for the hard-disk storage industry, which has repeatedly been reborn with the inventions of new approaches rather than by making previous approaches more efficient.

Two Dimensions of Adaptive Expertise. Recently, some have suggested that the concept of adaptive expertise involves at least two major dimensions: namely, processes that lead to *innovation* or invention and those that lead to *efficiency* through well-practiced routines (e.g., Schwartz, Bransford, & Sears, 2005). These two dimensions are illustrated in Fig. 10.2.

The horizontal dimension in Fig. 10.2 emphasizes efficiency; the vertical dimension emphasizes innovation. Sometimes these two dimensions are characterized as mutually exclusive ends of a continuum (e.g., high and low road transfer, Salomon & Perkins, 1989). However, because there are different processes involved, they are not necessarily exclusive of one another. Adaptive experts, for

⁸<http://www.businessweek.com/chapter/christensen.htm>

example, are presumably high on both dimensions (e.g., Gentner et al., 1997; Hatano & Inagaki, 1986; Wineburg, 1998).

It is noteworthy that different theorists and theoretical traditions can be represented by particular dimensions of Fig. 10.2. For example, Thorndike's classic studies, as well as the work of modern-day "direct instruction" advocates (e.g., Bereiter & Engelmann, 1966; Engelmann, 1992), provide examples of work on the efficiency dimension of expertise. The theories of Dewey, Piaget, and Vygotsky include principles that move one closer to the innovation dimension, although not necessarily. For example, Vygotsky's "zone of proximal development" could be applied to goals of either efficiency or innovation. Figure 10.2 reminds us that different dimensions of learning may exist.

Some educators, in contrasting theorists such as Dewey versus Thorndike, have asked, "Who is right?" The representation of adaptive expertise in Fig. 10.2 suggests that it may be more fruitful to ask instead how these different theorists and traditions can help us learn how people can become *both* efficient and innovative so that they can continually adapt to change.

Exploring What Success Looks Like

Central to the goal of helping students achieve important learning outcomes is to clarify what success looks like (e.g., Wiggins & McTighe, 1997). This is important both for issues of summative assessment (seeing how students perform at the end of some course or program of study) and formative assessment (creating measures that provide feedback to students and teachers plus opportunities for revision that speed learning progress over time; for example, see NRC, 2001; Darling-Hammond & Bransford, 2005). Vygotsky provides an excellent example of the need for both summative and formative assessments of progress:

Like a gardener who in appraising species for yield would proceed incorrectly if he considered only the ripe fruit in the orchard and did not know how to evaluate the condition of the trees that had not yet produced mature fruit, the psychologist who is limited to ascertaining what has matured, leaving what is maturing aside, will never be able to obtain any kind of true and complete representation of the internal state of the whole development. (1934/1987, p. 200)

As noted earlier, design theorists such as Wiggins and McTighe (1997) emphasize the importance of aligning formative and summative assessments with one's learning goals. This might sound obvious, but it is much trickier

to accomplish than first meets the eye—especially if the idea of "adaptive expertise" becomes an important goal for education in the 21st century.

Assessments of Efficiencies Versus Innovation

A number of researchers suggest that typically used assessments provide useful yet incomplete pictures of the kinds of skills, knowledge, and attitudes needed for success in the 21st century. In particular, if we return to the adaptive expertise dimensions shown in Fig. 10.2, there is a concern that most of today's assessments tend to be "efficiency" assessments. They are sensitive to well-learned routines and schema-driven processing but typically fail to capture the issues of flexibility that are important components of current thinking about the nature of adaptive expertise.

Efficiency assessments fit with (tacit or explicit) theories of transfer that focus on people's abilities to directly apply the procedures and schemas learned in the past to new problems and settings (e.g., Bereiter & Scardamalia, 1989, 1993; Bransford & Schwartz, 1999; Schwartz, Bransford & Sears, 2005). The expertise literature shows very clearly that well-established routines and schemas are an important characteristic of expertise. These allow people to free attentional resources that enable them to notice and deal with information that would overwhelm novices (e.g., beginning readers often have such problems with decoding fluency that they cannot attend to the meaning of what they read). Direct application theories of transfer typically involve tests of "sequestered problem solving" where people have access to what is currently "in their heads" (Bransford & Schwartz, 1999). The ability to directly and efficiently apply previously acquired skills and knowledge is important in many circumstances. If students have been trained to drive a car or fly a plane, for example, we want them to transfer directly from training to action. If they have to stop to read a driver's manual, or keep practicing parking by bumping other cars and learning from the experience, that's not a good outcome.

Nearly all summative measures such as standardized tests are "direct application" and "sequestered problem solving assessments." Many new variations on standardized testing such as "performance assessments" and "free response" items" (designed to go beyond multiple choice questions) are still mainly sequestered problem solving (SPS) assessments. Some argue (Bransford & Schwartz, 1999; Schwartz, Bransford & Sears, 2005) that SPS conceptualizations of transfer and assessment are responsible for much of the pessimism about evidence for transfer (e.g., Detterman & Sternberg, 1993). Equally if not more

importantly, when instructional programs are assessed by traditional assessments, they tend to get reduced to a “teach for efficiency” profile because this is an effective way to ensure good outcomes on typical tests. This is often true even for “thinking skills,” “problem solving,” and “creativity” courses, where SPS assessments often provide an impetus to teach in ways that prepare people for fixed sets of problem types that appear on subsequent tests (e.g., Bransford, Arbitman-Smith, Stein, & Vye, 1985; Schoenfeld, 1985).

Beyond Efficiency Measures. Research conducted during the past 5 years has spawned a wide variety of new ways to think about transfer (e.g., Mestre, 1994; Mestre, Thaden-Koch, Dufresne & Gerace, in press). One alternative to a “direct application view of learning and transfer” emphasizes people’s “preparation for future learning” (PFL). Here the focus shifts to assessments of people’s abilities to *learn* in knowledge-rich environments. When organizations hire new employees, they don’t expect them to have learned everything they need for successful adaptation. They want people who can learn, and they expect them to make use of resources (e.g., texts, computer programs, social networks of friends, and new colleagues) to facilitate this learning. The better prepared people are for future learning, the greater the transfer (in terms of speed and/or quality of new learning). Examples of ways to “prepare students for future learning” are explored in Schwartz and Bransford (1998), Bransford and Schwartz (1999), Schwartz and Martin (2004), Martin and Schwartz (2005), and Spiro, Vispoel, Schmitz, Samaratungavan, and Boeger (1987).

The PFL perspective is different from the older (but still important) learning-to-learn literature because the PFL’s primary focus is not on the existence of a set of general learning and memory skills (e.g. uses of mnemonic techniques) that are content free. The expertise literature (Chi et al., 1988; NRC, 2000) shows clearly how strategies and knowledge are highly interdependent. Broudy (1977) provides an example: “The concept of bacterial infection as learned in biology can operate even if only a skeletal notion of the theory and the facts supporting it can be recalled. Yet, we are told of cultures in which such a concept would not be part of the interpretive schemata” (p. 12). The absence of an idea of bacterial infection should have a strong effect on the nature of the hypotheses that people entertain in order to explain various illnesses, and hence would affect their abilities to learn more about causes of illness through further research and study, and the strategies one uses in order to solve new problems.

One of the implications of a switch from SPS to PFL thinking links to Norman’s (1993) work on designs that

“make us look smart” versus the opposite. Many SPS assessments of learning may make people look much less smart than is actually the case. For example, televised interviews with recent Harvard graduates revealed serious misconceptions about the cause of the seasons. Some believed that the cause of the seasons was dependent on how close the earth was to the sun, and others thought that clouds caused the seasons. By this assessment, their Ivy League education seemed useless. But this would be a severe misdiagnosis. If these students cared to learn about the cause of the seasons, there is little doubt they would be more prepared to do so than most young adults who never went to college. Ideally, preparation for future learning (PFL) assessments include opportunities for people to try out hunches, receive feedback, and attempt to revise based on the feedback. In contrast, typical tests provide few opportunities for feedback and revision—the only option is to provide one’s initial thoughts with no opportunities to test them and revise.

The idea that people may look better on PFL than SPS assessments does not imply that educators should use PFL assessments so they can be more satisfied with the quality of education. Rather, the implication is that SPS assessments can lead people to make incorrect decisions about the quality of educational experiences. Schwartz, Bransford, and Sears (2005) provide a number of examples of how PFL assessments reveal the effects of educational experiences whose benefits are invisible when standard SPS measures of assessment are used. A number of different research groups are currently exploring innovative ways to measure adaptive expertise (Crawford, Riel, & Schlager, 2005; Hatano, 2005; Hodge & Brophy, 2005; Martin, 2005; Petrosino, 2005; Schwartz, Blair, Davis, Chang, & Hartman, 2005; Walker, 2005).

Research on Instructional Strategies for Achieving Important Goals

Principles of learning have largely emphasized the development of routine expertise, where people become faster and more accurate at solving recurrent problems. For example, a great deal of current learning research is based on cognitive theories that emphasize procedures, scripts, and schemas (for definitions and examples see Anderson & Pearson, 1984; J. Anderson, 1976; Black and Bower, 1980; Bransford & Johnson, 1972; Schank & Abelson, 1977). These are very important for allowing people to solve particular sets of problems more efficiently. A great deal of the instruction in schools attempts to help students acquire schemas of particular problem types in order to increase problem solving efficiency by turning non-routine problems into routine problems. An example

involves problem types that take the form: *"Jim's parents live 60 miles away. He drove to their house at 60 mph and returned at 40 mph due to fog. What was his average speed?"* Most people simply say 50 mph—not realizing that Jim spends a longer amount of time going the slower speed so the average must be less than 50. There are a variety of problems of this type. When people are helped to acquire schemas that allow them to identify particular problem types, they are much less likely to get tripped up when later encountering similar examples.

Studies by Gick and Holyoak (1980, 1983) and others (e.g., Adams et al., 1988; Lockhart, Lamon, & Gick, 1988; NRC, 2000, Chapter 3) provide important information about learning conditions required to make "schema transfer" work (e.g., sufficient degrees of initial learning, applications of abstract concepts in a variety of different contexts, transfer appropriate processing). The acquisition of well-organized and fluently accessed procedures, scripts, and schemas is extremely important for effective performance—otherwise people are overwhelmed by attentional demands (e.g., see Bereiter & Scardamalia, 1993; NRC, 2000, Chapters 2 and 3). Learning these procedures and concepts "with understanding" typically provides better guidance for future actions than simply learning them by rote (e.g., NRC, 2000, 2005).

Beyond Schema-Based Applications. We argued earlier that an emphasis on innovation often includes the need to "let go" of previously acquired knowledge and skills and that this can have emotional consequences. This suggests that efficiency-oriented instruction that turns nonroutine into routine problems may need to be supplemented with different kinds of instruction that allow students to actively engage in inquiry and accept the emotional consequences of ambiguity and disconfirmation.

The conceptual change literature provides valuable information about the importance (and difficulties) of helping people resist over assimilation and change how they think (e.g., Carey, 2000; Gopnik et al., 1999; NRC, 2005). An emphasis on adaptive expertise reminds us that conceptual change is often needed in all areas of life. Indeed, failures to restructure our approaches to everyday social situations may frequently have more personal consequences than failures to restructure aspects of our scientific thinking (unless we are scientists dealing with a particular area of inquiry). For example, a person can live with the misconception that "the earth is hotter in the summer because it is closer to the sun." For most people this will not be life threatening or ruin their careers. However, failures to restructure our thinking in social settings often result in problematic actions. In the business literature, failures to change strategies in new contexts are often described as being due to "the tyranny of success"

(Robinson & Stern, 1997). People try the same thing that worked last time, but because the context is changed the old strategies no longer work. A simple example is a relatively new employee who gets along with others well and loves to engage in "around the water fountain" chats that provide important information about ways to improve the company. Then the employee is promoted to manager and all his colleagues treat him differently; his casual "around the water cooler" conversations no longer work for getting relevant information. Unless the new manager reinvents his way of gathering information, he will have a difficult time staying up to date.

Examples of ways to increase students responsive to innovation include metacognitively rich activities that engage them in (a) "knowledge building" rather than merely "knowledge telling" (Scardamalia & Bereiter, 1991), and (b) systematic inquiry with an emphasis on theory building and disconfirmation (e.g., Karmiloff-Smith & Inhelder, 1974/1975) rather than simply "following procedures for how to find some result" (e.g., NRC, 2005).

Some argue that innovation and change are facilitated by beginning instruction with "advance disorganizers" (e.g., Roediger, see Shaughnessy, 2002) rather than "advance organizers" (e.g., Ausubel, 1960). For example, students may first be asked to grapple with issues and try to solve them, which sets the stage for learning from and appreciating the kinds of insights developed over decades and centuries by experts in various disciplines. As an example, researchers have demonstrated the value of providing problem-solving and analysis experiences that create "times for telling" and help people resist overassimilation (e.g., Schwartz & Bransford, 1998; Schwartz & Martin, 2004; Schwartz, Bransford & Sears, 2005). This reverses the typical efficiency paradigm, which provides explicit problem-solving instruction followed by application problems at the end of the lecture or book chapter.

Being Innovative in Order to Increase Efficiency. Some researchers have attempted to design "working smart" environments that promote innovation in order to increase efficiency (Vye et al., 1998). Students learn about the general goal of efficiently solving a future set of *recurring* (quasi-repetitive) problems. In preparation for meeting this goal, they are encouraged to adopt, adapt, and invent "smart tools" that can help them work efficiently. Graphs, charts, spreadsheets, computer simulations, social networks, norms for distributed expertise, and a host of other resources are candidates for "working smart" (e.g., Bransford et al., 2000; Vye et al., 1998; Zech et al., 1998) by leveraging "distributed intelligence" (Pea, 1993). Working smart assessments combine the dimensions of innovation and efficiency shown in Fig. 10.2

LOOKING TOWARD THE FUTURE

How can work in the three research strands discussed earlier (see Fig. 10.1) be leveraged to move the field toward “a decade of synthesis”? By *synthesis*, we do not mean that all three of the research strands discussed previously will merge into one grand “melting pot” theory that eliminates the unique perspectives of each of them. Instead, we think that these strands can inform one another and, in the process, create more coherent and useful theories that better illuminate how, when, where, and why people learn. Examples of ways to accelerate collaboration are provided later.

Sharing Methodologies

One important area of connection among strands involves cases where their respective methodological strengths can be leveraged to increase the quality of research that is conducted. We discuss two examples—many more are possible as well (see Astuti, Solomon, & Carey, 2004).

Combining Experimental and Control Designs with Ethnographic Analyses. An example of sharing methodologies involves efforts by several researchers to combine the neuroscience, linguistic, and social-cognitive expertise of Strand 1 (implicit learning and the brain) with the use of fine-grained ethnographic analysis of social interactions that is characteristic of research in Strand 2 (the informal learning tradition).

As noted in Section 2, work by Kuhl and colleagues found that exposing American infants to play situations involving Chinese speakers enabled the American children to maintain their abilities to differentiate Chinese sounds, instead of losing this ability as is normally the case. However, this worked only under conditions where there was interactive play between the children and live Chinese speakers. This maintenance did not occur when the Chinese speakers were shown via television, despite the fact that the media could be considered to present “supernormal” stimuli with beautiful records of the facial expressions and lip movements by the mentors as they talked in Chinese.

Work in progress will replicate the previous study (this time with Spanish as the new language) and add researchers from the informal learning with expertise in social interaction analysis. The goal is to provide information about the relationships between the quality of child-mentor interactions and the quality of learning. Interestingly, issues about the kinds of video records needed for this kind of analysis had to be addressed in order to

develop this research collaboration. This is a good example of ways that implicit learning and informal learning researchers can both benefit from collaborative work.

Exploring Reasoning in Everyday Versus Laboratory Settings. A second example of potential benefits of studying the same or similar topic from the perspective of between different research strands involves the conjecture that children often seem to employ sophisticated arguments in everyday, informal settings, yet may have difficulty constructing scientific arguments in the classroom and in the laboratory (e.g., Bell, 2004; Bell & Linn, 2000). Can in-depth understanding of children’s out-of-school linguistic competencies with argument directly inform the design of formal science instruction where students learn through scientific argumentation and debate? Do laboratory studies of children’s knowledge of reasoning mispredict their everyday argumentation and thinking? And if so, why? These kinds of questions can be most directly explored through a coordination of ethnographic, lab-based, and classroom intervention research. An exploration of these kinds of questions seems important and fruitful to explore in order to better understand the everyday competencies with argument that children develop in different contexts, to refine lab-based protocols for gauging children’s theory of mind, and to improve the design of learning environments for scaffolding argumentation.

Perspectives on People Knowledge and the Social Brain

Researchers from all three of the strands discussed earlier are beginning to explore implications of the idea that people—from infancy to adulthood—seem to naturally pay attention to other people and to learn from them. For example, Strand 1 researchers note that human children are socially attuned from birth—infants are particularly interested in human faces and voices and learn a great deal through observing and imitating the behaviors, customs, and use of technologies in their culture (e.g., Gopnik et al., 1999; Meltzoff, 2005). Similarly neuroscientists are beginning to tackle higher-order questions, such as the brain bases of empathy in adults (Jackson et al., 2005) and cooperative learning versus competition (Decety, Jackson, Sommerville, Chaminade, & Meltzoff, 2004).

Informal learning researchers note how groups where people know one another function differently from groups of relative strangers. Experimental research has shown that collaboration can lead to better problem solving and learning than individual work (Barron, 2000; Johnson & Johnson, 1981; Stevens & Slavin, 1995).

Cognitive researchers have also been concerned with explaining why groups outperform individuals, and several cognitive mechanisms have been proposed and empirically documented. These include opportunities to share original insights (Bos, 1937), resolve differing perspectives through argument (Amigues, 1988; Phelps & Damon, 1989), explain one's thinking about a phenomenon (King, 1990; Webb, Troper, & Fall, 1995), provide critique (Bos, 1937), observe the strategies of others (Azmitia & Montgomery, 1993), and listen to explanations (Coleman, 1988; Hatano & Inagaki, 1991; Webb, 1989).

Detailed video analysis of interactions has revealed that in group learning situations, capitalizing on collective knowledge is both a social and a cognitive endeavor, and that the quality of the conversations and nature of shared engagement mediates how much is learned (Barron, 2003). Other experimental research has demonstrated that friends have better conversations during problem-solving activities than acquaintances, and this translates into more learning for individuals. (e.g., Azmitia & Montgomery, 1993; Miell & McDonald, 2000). Friends are more likely to elaborate and extend the ideas of their partners. They also talk more and offer more ideas to one another. Past experiences with one another allow for this kind of exchange as well as motivation to nurture the relationship. These findings are relevant for understanding how schools can promote better collaborative skills—an area of research that is just beginning. Comparative studies suggest that some schools prepare students to work together more than others (Matusov, Bell, & Rogoff, 2002).

Strand 3 researchers have explored how knowledge of the personal backgrounds of other people can produce powerful changes in opinions about them (Lin & Bransford, 2005), and how knowledge of people with whom one is talking can lead to a number of shortcuts for effective communication (Bransford, Derry, Berliner, Hammerness, & Beckett, 2005). Lin and Bransford (2005) also note that experts' knowledge seem to be organized around people in their field as well as around abstract concepts, yet few studies of expertise have explored this idea (for an exception see Loftus & Loftus, 1974). Overall, there may be considerable potential to increase student learning by using technologies that humanize instruction in ways that let students learn about content while also learning about the people who have developed that content. Initial work by Magnusson & Palincsar (2005), Hong & Lin (2005), and Vye, Bransford, Davis, and Lee (in preparation) support this point of view.

Our understanding of people knowledge and its role in learning can be enhanced by comparing methods from different research traditions. For example, imagine that

you are communicating via e-mail with someone you know well versus a stranger. Are there unique neural patterns and arousal patterns associated with these different conditions? Similarly, is it easier to learn new information from well-known people because of increased abilities to (implicitly) elaborate based on knowing the background of the people and being able to identify affectively with their struggles and questions (e.g., Lin & Bransford, 2005; Magnusson & Palincsar, 2005; Hong & Lin, 2005). Questions such as these could have a dramatic impact on new ways to create more "people centered" curricula in formal education. The issue of "people knowledge" and its benefits for learning seems ripe for collaboration across all three of the research strands illustrated in Fig. 10.1.

Sharing Research Tools

A second way to accelerate synthesis across research strands is to share research tools that make it easier to study learning and which can help promulgate affiliated theory and methodologies. The Pittsburgh Science of Learning Center (www.learnlab.org) provides an interesting model for how this might be accomplished. The Center has developed an innovative paradigm for experimentation on learning that they call LearnLab. The LearnLab environment consists of seven "highly instrumented courses" in mathematics, science, and language at the high school and college levels. Each course is available for use in "real" classrooms and incorporates state-of-the-art design features to promote learning; including, for example, intelligent tutors and peer dialog capabilities. An especially exciting aspect of this vision is that LearnLab includes advanced technology for researchers across the country to use to design and conduct studies in the context of courses—an *in vivo* lab. This is facilitated by the availability of authoring tools, student interaction data collection tools, and tools for data analysis built into the technology-based courseware.

Members of the Pittsburgh Center argue—as others have too—that learning science research is currently (1) either rigorous or realistic, but rarely both, (b) fine grain or long duration, but rarely both, and (c) mostly inadequate from the standpoint of measuring learning in a robust way. LearnLab was developed to address each of these issues and to promote a widespread research initiative for the field that is high quality and can produce important findings that can be effectively and rapidly implemented in classrooms.

Needless to say, any set of tools provides both opportunities and constraints. In the context of the present chapter, it will be useful to see whether and how

researchers from different strands view the LearnLab tools from their unique perspectives. Will they seek to redesign the tools, or can they work with them to create a variety of unique applications? Whatever the conclusions, the Learnlab concepts seems like a powerful way to help the field increase its ability to communicate and advance.

Many other tools are being developed and shared by members of the broader learning research communities. For example, a number of different groups are using technology tools for helping make students' thinking more visible (e.g., Minstrell, 2005; Penuel & Yarnall, 2005). Members of these different groups are beginning to collaborate in order to find what works well (e.g., the nature of the questions that are asked) and what needs improving. SRI's Web site provides a number of powerful examples of lessons learned (www.SRI.com); so does the "Just in Time Teaching" Web site (www.JITT.org).

Other tools are being developed and shared that permit the research community to capture information that otherwise would be difficult to capture. Examples include sophisticated video analysis and collaboration tools such as *VideoTraces* (Stevens, Cherry & Fournier, 2001; Stevens & Hall, 1997; Stevens & Toro-Martell, in press; Stevens, in press) and *DIVER* (Pea et al., 2004; Pea, in press), which enables collaborative video analysis and the functions of a "digital video collaboratory" for cumulative knowledge building from video datasets. New generations of learning management systems are also making it possible to study the effects of a variety of challenge-based approaches to instruction and capture data from individual students as they proceed through these (e.g., see the CAPE system at www.VaNTH.org). Other groups are using shared data sets as anchoring points for uncovering multiple perspectives on common issues (e.g., MacWhinney et al., 2004). Overall, the shared use of shared tools provides a common ground for communication that increases the probability for meaningful across-strand conversations.

Searching for "Conceptual Collisions"

In addition to sharing methods and tools is the broader strategy of actively attempting to identify fruitful "conceptual collisions" among different research traditions. Because of different ways of talking about phenomena and doing research, it is easy for members of different strands to talk past one another rather than effectively communicate (e.g., Kuhn, 1962). Attempts to look at similar phenomena from multiple perspectives (what some have called *anchored collaboration*, CTGV, 1997) can help surface (often tacit) assumptions that can then be compared. There are at least two approaches one might take toward conceptual collisions. One anchors the collision

around important principles that guide thinking about learning. The other anchors the collision around common phenomena.

Conceptual Collisions Around Important Claims

Several reports from the National Academy of Sciences (NRC, 2000, 2005) have identified three principles of learning that are important for helping students move along a pathway to develop expertise (including adaptive expertise). We can use these principles to give examples of how conceptual collisions play out. The three principles are:

1. Students come to the classroom with preconceptions about how the world works. If their initial understanding is not engaged, they may fail to grasp the new concepts and information, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom.
2. To develop competence in an area of inquiry, students must (a) have a deep foundation of factual knowledge, (b) understand facts and ideas in the context of a conceptual framework, and (c) organize knowledge in ways that facilitate retrieval and application.
3. A "metacognitive" approach to instruction can help students learn to take control of their own learning by defining learning goals and actively monitoring their progress in achieving them.

Preconceptions. The three traditions of research add complementary perspectives to understanding the role of preconceptions. Strand 3 points to the efficiency × innovation characterization of adaptive expertise illustrated in Fig. 10.2. The idea that all learners begin with preconceptions can be represented by assuming that they all start from their existing "efficiencies"—their habitual ways of thinking about and doing things. This efficient knowledge is critically important. People need prior knowledge to make sense of new situations, and they need fluent access to this knowledge so that they can "reinvest" their attentional resources in other matters (e.g., Bereiter & Scardamalia, 1993). Often, however, efficient access to knowledge and skills results in the overassimilation of new ideas to existing schemas as described in the language cases of Strand 1 and also by Strand 3 researchers in other domains (e.g., Schwartz & Bransford, 1998; Wineburg, 1998). One might hypothesize that—at least for some concepts and procedures—the more automated (and tacit) one's current scripts and schemas (characterized by moving to the right on the efficiency dimension), the harder it may be to resist the urge to

overassimilate. This would correspond to the Strand 1 argument that implicit learning leads to neural commitment and ways of thinking that become highly efficient, but sometimes at the expense of learning new ways of thinking.

As discussed in the first section, Strand 1 researchers emphasize both the advantages and the disadvantages of neural commitment in areas of expertise. Disadvantages are illustrated in second language learning, which is made more difficult if the second language is learned late in life when the brain is already committed to the way of listening and processing language that is embodied in one's "mother tongue." In this case an implication of Strand 1 theorizing is that new learning will require exposure to patterns of covariance that fall outside the normal pattern—experience that does not support the initial "mental filter" or preconception. The exposure to new instances may need to have a frequency that can outweigh the huge number of original instances that led to the neural commitment (or preconception) to begin with.

Work from Strand 2 draws our attention to instances outside of language learning where it may not be maximally adaptive or desirable to sidestep preconceptions rather than replace them. For example, they might argue that it is important to develop patterns of social participation and mediation that help people transition back and forth between everyday preconceptions and the more formal treatments characteristic of school. Overall, the three strands provide different perspectives on a fundamental principle, and each strand can help nuance one another's claims.

Learning with Understanding. A number of studies show that novices often focus on surface features of concepts (e.g., Chi, Feltovich, & Glaser, 1981) and that learning with understanding can increase the flexibility of transfer (e.g., Judd, 1908; NRC, 2000; Wertheimer, 1959). Learning with understanding involves developing a recognition of the deep structure of an idea or situation, including the "why." Strand 2 proposes that this recognition arises from the significance and meaning provided by a matrix of social practices. For example, other people model the value and identity attached to particular interpretations. Strand 1 agrees with Strand 2 on the significance of social interaction, with a special emphasis on learning through observing the behaviors and customs of other people. To explain why learning with understanding transfers better than "brute learning," Strand 1 might argue that "understanding" usually means that people have seen enough instances that they can infer (albeit sometimes through an "unconscious inference") the causal structure beneath a variety of instances (e.g., Gopnik et al., 1999).

Strand 3 is more likely to focus on the structural characteristics of knowledge that support understanding, which

includes knowledge of assumptions about when a particular body of knowledge applies and the implications that knowledge yields. It examines the types of designed environments that help people explicitly understand why and how particular aspects of their knowledge (including skills) are relevant.

Metacognition. The third learning principle noted earlier involves helping students learn to take a metacognitive stance to their own learning—complete with habits of mind for self-generated inquiry and self-assessment. There is a strong body of evidence showing the value of being reflective about learning. For example, students who were directed to engage in self-explanation as they solved mathematics problems developed deeper conceptual understanding than students who solved those same problems but did not engage in self-explanation (Chi, Bassok, Lewis, Reimann, & Glaser, 1989). This was true even though a common time limitation on both groups meant that the self-explaining students solved fewer problems in total.

Similar findings about the value of metacognitive processing have been found in science learning (e.g., Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996; Lin & Lehman, 1999; NRC, 2000; Vye et al., 1998; White & Frederiksen, 1998), mathematics (Shoafeld, 1992) and reading comprehension (e.g., Brown & Campione, 1994, 1996; Palincsar & Brown, 1989; Pressley, 1995).

Donovan and Bransford (2005) emphasize that metacognition is not a "knowledge free skill" that works independently of content knowledge. To be optimally effective, metacognitive strategies need to be taught in the context of the individual subject areas (e.g., Vye et al., 1998). Many of the questions one asks in the monitoring process change to some extent with the subject, though there is certainly a great deal of overlap. In history, for example, we want students to ask from what perspective the author writes, and about the purpose of his or her writing—questions that are often less relevant in mathematics. In mathematics, on the other hand, we want students to monitor their progress toward a solution to a problem, and reflect on whether that solution is within expectation. In writing, we want students to reflect on the audience, what they will understand, and what more they need to know. In the sciences and in history, the question "What is the evidence?" is especially important, as is the mind-set of looking for disconfirming as well as confirming evidence. *How Students Learn* (2005) provides rich examples of metacognitive monitoring as students learn about mathematics, science, and history.

Many researchers across the three traditions view the development of metacognition as the result of social processes. For example, the notion of "cognitive apprenticeship" emphasized in Strand 2 (Brown, Collins, & Duguid, 1989) can provide learners a chance to

internalize the reflective practices of an expert. Here, the focus is on the social and cultural context that supports the development of metacognition for recurrent situations. Strand 1 also emphasizes the developmental aspects of metacognition, examining it as emergent from simpler beginnings that at first did not include the "meta" component. In this regard, Strand 1's emphasis on the "social brain" (e.g., Kuhl, 2004; Meltzoff & Decety, 2003) and the young child's natural attunement to other people may provide a foundation from which children can bootstrap to more conscious and metacognitive ways of understanding their own thoughts and the thoughts of others (Meltzoff, 2005). Metacognition itself may not emerge through a maturational process, but as a downstream development outcome of a human brain (and child) cared for by other people (Gopnik & Meltzoff, 1997; Gopnik et al., 1999).

Strand 3 is particularly concerned with the types of activities that promote the kinds of metacognitive activities that support adaptation and innovation. So, rather than only entraining on a set of metacognitive routines or skills that improve the efficiency at a recurrent set of tasks, an additional question is how to help people develop characteristics of adaptive expertise that include the habits of mind of reflecting on situations and actions with the goal of trying out new ideas, moving away from existing comfort zones, and actively seeking feedback in order to test new ideas.

For metacognition, as with preconceptions and learning with understanding, there are areas of substantial overlap between the traditions. It is useful to explore the overlaps and determine if there is a larger theoretical framework that can organize the commonalities. However, there are also significant differences in the particular phenomena of interest, the types of explanations that are satisfying, and the language for expressing explanations.

Overall, multiple perspectives anchored around key principles of learning are a fruitful approach to the identification of conceptual collisions, but they also represent a difficult approach because of the need for different strands to learn to talk with one another at relatively abstract levels of discourse. An alternative (complementary) approach to exploring conceptual collisions is to collect multiple perspectives on relatively concrete anchoring phenomenon. An example is provided next.

Anchoring Collaborations Around Phenomena

Members of the LIFE Center (www.LIFE-slc.org) have begun to use anchored collaborations around specific phenomena as a way to surface interesting conceptual collisions across research traditions. One way to do this is to create vignettes that people from different strands are

asked to comment on. To illustrate, consider a vignette of novices going in a boat with an expert fisherman who takes them to a good spot on the lake, helps them select the right bait and set the hook at the right depth, shows them how to set the hook, and so forth. Some of the novices catch several fish and feel good about their efforts. A month later they come back to the lake by themselves. They return to the spot and repeat the previous behaviors because they were successful earlier. The challenge asks people to respond from the perspective of implicit learning, informal learning, and designs for formal learning. Several "collisions of ideas" emerged from this simple exercise that were surprising to the LIFE members and raised important questions about learning.

Issue 1: What Do We Really Mean by "Learning from Experience"? The people who created the fishing challenge were from Strand 3 (formal learning and beyond) and were interested in whether researchers from Strand 1 (implicit learning and brain) and Strand 2 (informal learning) would bring up differences between "learning by rote" versus "learning with understanding" (e.g., Judd, 1908). Differences on a "rote-understanding" dimension of the fishing vignette could presumably have a large effect on transfer. For example, if one understands the reasons for the mentor's fishing decisions and activities (including linking them to changing needs of fish and their life in a lake that also changes), coming to the lake 1 month later and slavishly repeating the previous behaviors without variation and adaptation to the current situation may be undesirable. These ideas suggest the need to clarify what "learning from experience" (be it implicit, informal or formal learning) might mean.

Issue 2: Multiple Levels of Simultaneous Learning. Comments on the challenge from Strand 1 researchers (implicit learning and brain) suggested that multiple levels of learning could be occurring simultaneously. These comments were a surprise to the people who had developed the vignette (Strand 3 researchers). The latter had focused solely on the "intended curriculum" of learning to fish and ignored all the other possible lessons embedded in this general scenario. Several possible examples of learning that were suggested by Strand 1 researchers appear in Table 10.1.

The idea that multiple lessons may be learned in any slice of life is a very important potential insight. As noted earlier, the developers of the vignette had focused solely on the "intended curriculum" of learning to fish. Similarly, in schools we often talk about students who do and do not learn the intended curriculum, but we often ignore the many things that they are learning. Examples might include "I am good (or not good) at X (reading, mathematics, science, art, music, etc.)" or "I am (or am not) liked

TABLE 10.1.

1. Learning About Morality—The fisherman may or may not have a license. The fisherman may catch only his limit or “assume no one will know” and overfish. The child will implicitly learn from this. The fisherman may catch more than he can eat for the thrill of the hunt, or only take from the environment what he needs.

2. Learning About Philosophy—When the fish aren’t biting on the lures, Joe Hunter threads live worms to his hook, because they are “best for catching fish.” But another parent goes out on a boat with his child and refuses to fish even with lures. Without saying a word, the child learns different lessons about human kinship and distance from other living things, different lessons about whether humans can or should use other animate beings as “a means” to the child’s own ends.

3. Learning About People (Motives and Attitudes)—When going fishing, one person may want to talk a lot about the day’s problems (“complaining about folks back home”) and another may want to “be in the moment, at one with nature.” The child will absorb this implicit attitude towards people and the environment. When the child grows up, this pattern may even be repeated, because it is deeply engrained with what it means to “fish on weekends.”

4. Learning About Stereotypes—The Challenge shows a male fisherman. This is a gender stereotype. One child may learn that fishing is a time for father-son bonding. Another child may learn that it’s a great time for “father-daughter” or “mother-daughter” or “whole-family” bonding. Children implicitly learn from what we do. The information is there, and they learn a “way of life” from it.

5. Learning of Physics—When the novice gets in the canoe it rocks. After a full summer of canoeing the lesson learned may be that “getting low” in the boat prevents rocking. This in turn may give an intuitive grounding for later learning about “center of gravity.” The child knows nothing about “center of gravity” or center of buoyancy as yet, but the child does learn that it helps to “get low” and may be able to draw on this experience later in life. When the physics professor explains the center of gravity concept in class, the child has the potential to relate it to previously learned physical intuitions. Of course, as noted earlier, everyday experiences (e.g., related to physics) can create misconceptions as well, especially in the cases where advanced scientific explanations are not in line with our everyday intuitive “felt experience.”

by my peers or my teacher.” As noted earlier, Holt (1964) argued that the key issue of learning, is never *whether* students are learning, but *what* they learn.

Do people really learn multiple lessons in various “slices of life”? Doesn’t this clash with the idea that attention has to be explicitly focused on particular events in order to learn? Or is there indeed a great deal of “non-focused” background learning that functions as a kind of “hidden curriculum”? If the latter, what kinds of data exist, or could be collected, to support the “multiple dimensions of (often implicit) learning” point of view? The discussion of media research and its emphasis on subtle but powerful effects on behavior (discussed in the first section) provides important clues about exploring this question. So does the literature on implicit learning (Reber, 1993) and implicit memory (Shaughnessy, 2002).

The issue of “multiple levels of learning” raises possibilities that might help us rethink the design of informal and formal educational environments. For example, consider phonics taught in a stripped-down worksheet-centered context. This may end up depriving students of many opportunities for implicit learning compared to contexts where a great deal of language-rich interactions accompany a focus on phonics (e.g., Valdes, Bunch, Snow, Lee, & Matos, 2005). The language-rich experiences may not show up on tests of phonics knowledge, but they may well provide crucial support for later learning of vocabulary and content-specific reading abilities. The same is true of science lessons, mathematics lessons, etc. Possibilities such as this are too potentially important for researchers to ignore.

Issue 3: Multiple Avenues for Participation. Responses to the fishing scenario from Strand 2 researchers surfaced another important issue: namely, questions about the units of analysis for what counts as success. A typical unit of analysis in school is individual students—and they are typically compared to other students on the same criteria. In informal settings the unit is often the group and different people may contribute in very different ways (see Section 2).

On a fishing trip, the fishing party as a whole may have success at catching fish even though a few people do not. But even the non-fish-catchers can share in the success *if* they have been able to do things that helped everyone else. For example, one person may be good at using a trolling motor, another may be great at helping others land their fish with a net, another at cleaning fish, another at telling stories that keep the group motivated during “dry” spells, and so forth. There are many possible roles for participation, and success is often a function of the distributed expertise of the group (e.g., see Hutchins, 1993). Note that the issue here goes beyond the idea of group versus individual learning opportunities. In school, group assignments still often end by assessing all students on the same criteria.

In addition, school assignments often do not provide genuine opportunities for a wide range of distributed expertise. In many nonschool environments, it is the diversity of expertise that makes for success and is celebrated. Is it possible to create “diversity of expertise” curricula in science, mathematics, etc., so that people can each bring particular subsets of skills to an overall project (e.g., where some excel at the visual representation of mathematical ideas, some have great proficiency with proportional reasoning, some are wonderful at formulating formal proofs, etc.)? For examples, see Brown and Campione (1994) and CTGV (2000).

Multiple pathways toward success should be able to increase motivation because each person is likely to be

able to contribute while also learning new skills and concepts (e.g., each person is a [relative] expert as well as a novice). This is a very different experience from being in the bottom quartile in some particular class (for example) and never having a chance to also be good (and appreciated) at other things in that class.

Issue 4: Multiple Cycles That Encourage “Working Smarter”. Issues of multiple types and levels of participation are also related to another issues that LIFE researchers highlighted in the context of the fishing vignette: namely, that learning to fish is not typically a “one chance only” activity. Instead, most people fish many times and, between trips, have opportunities to think about what worked and find ideas, tools, and strategies for doing better the next time. In short, fishing involves what we earlier (Section 3) called “quasi-repetitive activity cycles” (QRACS) that provide opportunities for feedback, reflection, and revision—in part by learning to “work smarter” the next time around.

“Working smart” can involve practicing isolated skills such as learning to cast by putting up a target in the back yard or learning to tie knots that hold on lures. Nevertheless, people get to practice while also having the big picture of why they are practicing, and they have multiple opportunities to try the “big task” (i.e., catching fish).

A way to introduce people to fishing that is more similar to school might be to learn to tie knots, then to tie on hooks, then to bait hooks, then to cast, etc. In this model, people do not get to try their hand at fishing until they master each of the building blocks. If fishing were taught this way, it is likely that many would lose interest; others would learn more slowly because they don’t know why they are practicing. In a previous section we discussed “working smart” curricula that utilize some of the QRAC structures that seem characteristic of many activities in the workplace and everyday life.

Issue 5: Assessments of Progress. Related to ideas about different kinds of participation opportunities over time is the fundamental issue of assessment. Do we hold all people accountable for catching a certain amount of fish at each age level, for example, or do we celebrate multiple avenues of individual progress? There appear to be many reasons for preferring the latter. One person might have great trouble tying hooks but be excellent at setting the hook once the fish bite. Or as noted earlier the person may be skilled at running a boat, keeping others entertained during “dry spots,” etc. People on a fishing trip would probably make note of these individual contributions—and would probably also be patient as each learns to do things that are hard for him or her (e.g., tie or bait hooks).

Academic environments often fail to celebrate unique strengths and tend to look at placements within a class

(e.g., bottom 10 percent) rather than progress over time. In addition, assessments often fail to fully consider a wide range of possible skills that can make people successful. In fishing, for example, one could imagine an arthritic grandfather who can no longer cast and catch fish but knows where to fish and knows whom to invite to have a great outing. He could be considered a great fisherman because he knows how to create distributed expertise environments. The pursuit of new ways of thinking about assessment is a fundamental issue that we believe will receive more and more attention in the next 10 years.

SUMMARY

Our goal in this chapter has been to argue for the benefits of treating the next decade as a decade for synergy among different traditions of learning theorists. We built on previous work in this area (e.g., Greeno et al., 1996) and discussed three areas of research that seem well-positioned to inform one another: (1) Implicit Learning and Brain; (2) Informal Learning; (3) Designs for Formal Learning and Beyond.

Discussion in the first three sections provided samples of research and theorizing from each of these areas. Our reviews of these areas was far from exhaustive, but we hope the discussions provided sufficient information to motivate readers to explore each of these areas in more detail.

In the last section of this chapter we discussed some initial strategies for accelerating the movement toward synergy among different learning traditions. These included sharing methods, sharing research tools, and actively searching for “conceptual collisions” that can, we hope, uncover new ways of thinking about learning and educational design. One set of conceptual collisions that we discussed was anchored around basic principles of learning that have been discussed most explicitly in the context of research in Strand 3 settings (e.g., Darling-Hammond & Bransford, 2005; NRC, 2000, 2005). A second set was anchored around a simple vignette of learning to fish. This fishing exercise was conducted by members of the LIFE Center, and everyone who participated learned something fundamental from seeing others’ points of view.

This chapter is being written at the beginning of what we are calling a decade for synthesis. There is a great deal of work to be accomplished. We realize that our discussion of the potentially relevant research literature barely scratches the surface of what has actually been accomplished by learning research. Furthermore, our discussion of strategies for synthesis across strands represents only a subset of what we can do as a field. However, we hope that this chapter provides a rationale for the value of pulling

different research traditions together—and searching for and celebrating collisions among them—in order to address the formidable but exciting challenges of helping all learners succeed.

ACKNOWLEDGMENTS

This work was supported by a grant from the National Science Foundation (NSF#0354453). Any opin-

ions, findings and conclusions expressed in the paper are those of the authors and do not necessarily reflect the views of the National Science Foundation. The authors thank the following individuals for their contributions to the chapter: Leah Bricker, Hank Clark, Barbara Conboy, Joan Davis, Katie Hardin, Toshi Imada, Beth Koemans, Tiffany Lee, Laurie McCarthy, Maisy McGaughey, Raj Raizada, Suzanne Reeve, Maritza Riveragaxiola, Tom Satwicz, Yang Zhang, and Heather Toomey Zimmerman.

References

Ackerman, P. (2003). Cognitive ability and non-ability trait determinants of expertise. *Educational Researcher*, 32, 15–20.

Adams, L., Kasserman, J., Yearwood, A., Perfetto, G., Bransford, J., & Franks, J. (1988). The effects of facts versus problem-oriented acquisition. *Memory & Cognition*, 16, 167–175.

Adamson, L. B., & Bakeman, R. (1991). The development of shared attention during infancy. In R. Vasta (Ed.), *Annals of child development*, 8, 1–41.

Alexander, P. (2003). The development of expertise: The journey from acclimation to proficiency. *Educational Researcher*, 32, 10–14.

Amigues, R. (1988). Peer interaction in solving physics problems: Sociocognitive confrontation and metacognitive aspects. *Journal of Experimental Child Psychology*, 45(1), 141–158.

Anderson, J. R. (1976). *Language, memory and thought*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Anderson, J. R. (Ed.) (1981). *Cognitive skills and their acquisition*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Anderson, D. R., & Lorch, E. P. (1983). Looking at television: Action or reaction? In J. Bryant & D. R. Anderson (Eds.), *Children's understanding of television: Research on attention and comprehension* (pp. 1–33). New York: Academic Press.

Anderson, R. C., & Pearson, P. D. (1984). A schema-theoretic view of basic processes in reading comprehension. In P. D. Pearson (Ed.), *Handbook of reading research* (pp. 255–291). New York: Longman.

Astuti, R., Solomon, G., & Carey, S. (2004). Constraints on conceptual development: A case study of the acquisition of folk-biological and folksociological knowledge in Madagascar. *Monographs of the Society for Research in Child Development*, 69(3), 1–163.

Ausubel, D.P. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology*, 51, 267–272.

Azmitia, M., & Montgomery, R. (1993). Friendship, transactional dialogues, and the development of scientific reasoning. *Social Development*, 2(3), 202–221.

Barron, B. (2000). Problem solving in video-based microworlds: Collaborative and individual outcomes of high achieving sixth grade students. *Journal of Educational Psychology*, 92, 391–398.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences*, 12, 307–359.

Barron, B. (2004). Learning ecologies for technological fluency: Gender and experience differences. *Journal of Educational Computing Research*, 31(1), 1–36.

Barron, B. Processes of knowledge growth across contexts: A learning ecologies perspective. Submitted for publication.

Beach, K. D. (1993). Becoming a bartender: The role of external memory cues in a work-directed educational activity. *Journal of Applied Cognitive Psychology*, 7, 191–204.

Becker, H. S. (1953). Becoming a marihuana user. *American Journal of Sociology*, 59, 235–242.

Becker, H. S. (1972). A school is a lousy place to learn anything in. *American Behavioral Scientist*, 16, 85–105.

Becker, H. S. (1996). The epistemology of qualitative research. In R. Jessor, A. Colby & R. Schweder (Eds.), *Essays on ethnography and human development* (pp. 53–71). Chicago: University of Chicago Press.

Becker, H. S., & Carper, J. (1956). The elements of identification with an occupation. *American Sociological Review*, 21(3), 341–348.

Bell, P. (2004). Promoting students' argument construction and collaborative debate in the science classroom. In M. C. Linn & E. A. Davis & P. Bell (Eds.), *Internet environments for science education* (pp. 115–143). Mahwah, NJ: Lawrence Erlbaum Associates.

Bell, P., & Linn, M. C. (2000). Scientific arguments as learning artifacts: Designing for learning from the web with KIE. *International Journal of Science Education*, 22(8), 797–817.

Benoit, W. L., & Hansen, G. J. (2004). Presidential debate watching, issue knowledge, character evaluation, and vote choice. *Human Communication Research*, 30(1), 121–144.

Bereiter, C., & Scardamalia, M. (1989). Intentional learning as a goal of instruction. In L.B. Resnick (Ed.), *Knowing, learning,*

and instruction: Essays in honor of Robert Glaser (pp. 361-392). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bereiter, C., & Engelmann, S. (1966). *Teaching disadvantaged children in the preschool*. Englewood Cliffs, NJ: Prentice-Hall.

Bereiter, C., & Scardamalia, M. (1993). *Surpassing ourselves: An inquiry into the nature and implications of expertise*. Chicago: Open Court.

Berliner, D. C. (1991). Educational psychology and pedagogical expertise: New findings and new opportunities for thinking about training. *Educational Psychologist*, 26(2), 145-155.

Berliner, D. C. (2001). Learning about and learning from expert teachers. *International Journal of Educational Research*, 35(5), 463-468.

Berry, D., & Broadbent, D. (1988). Interactive tasks and the implicit-explicit distinction. *British Journal of Psychology*, 79, 251-272.

Berry, D. C. (Ed.). (1997). *How implicit is implicit learning*. New York: Oxford University Press.

Bever, T. G. (1982). Regression in the service of development. In Bever et al. (Eds.), *Regression in child development* (pp. 153-188). Hillsdale, NJ: Lawrence Erlbaum Associates.

Black, J., & Bower, G. (1980). Story understanding as problem-solving. *Poetics*, 9, 223-250.

Bos, M.C. (1937). Experimental study of productive collaboration. *Acta Psychologica*, 3, 315-426.

Bransford, J.D., Arbitman-Smith, R., Stein, B.S., Vye, N.J. (1985). Three approaches to improving thinking and learning skills. In R. Segal, S. Chipman, & R. Glaser (Eds.), *Thinking and learning skills: Relating instruction to basic research* (Vol. 1, pp. 133-206). Hillsdale, NJ: Lawrence Erlbaum Associates.

Bransford, J., Derry, S., Berliner, D., Hammerness, K., & Beckett, K. (2005). Theories of learning and their roles in teaching. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world* (pp. 40-87). San Francisco: Jossey-Bass.

Bransford, J. D., & Heldmeyer, K. (1983). Learning from children learning. In J. Bisanz, G. Bisanz, & R. Kail (Eds.), *Learning in children: Progress in cognitive development research* (pp. 171-190). New York: Springer.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior*, 11, 717-726.

Bransford, J. D., & Nitsch, K. E. (1978). Coming to understand things we could not previously understand. In J. F. Kavanagh & W. Strange (Eds.), *Speech and language in the laboratory, school, and clinic* (pp. 267-301). Cambridge, MA: MIT Press.

Bransford, J. D., & Schwartz, D. (1999). Rethinking transfer: A simple proposal with multiple implications. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 61-100). Washington, DC: American Educational Research Association.

Bransford, J. D., Vye, N., Bateman, H., Brophy, S., & Roselli, R. (2004). Vanderbilt's Amigo³ project: Knowledge of how people learn enters cyberspace. In T. Duffy & J. Kirkley (Eds.), *Learner-centered theory and practice in distance education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Bransford, J. D., Zech, L., Schwartz, D. L., Barron B. J., Vye, N. J., & Cognition and Technology Group at Vanderbilt (2000). Design environments that invite and sustain mathematical thinking. In P. Cobb (Ed.), *Symbolizing, communicating and mathematizing: Perspectives on discourse, tools, and instructional design* (pp. 275-324). Mahwah, NJ: Lawrence Erlbaum Associates.

Bronfenbrenner, U. (1977). Toward an experimental ecology of human development. *American Psychologist*, 32, 513-531.

Brophy, S. P. (2001). *Exploring the implication of an expert blind spot on learning*. Unpublished manuscript, Vanderbilt University, Nashville, TN.

Broudy, H. S. (1977). Types of knowledge and purposes of education. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge* (pp. 1-17). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *Journal of the Learning Sciences*, 2(2), 141-178.

Brown, A. L., Bransford, J. D., Ferrara, R. A., & Campione, J. C. (1983). Learning, remembering, and understanding. In J. H. Flavell & E. M. Markman (Eds.), *Handbook of child psychology: Cognitive development* (Vol. 3, pp. 77-166). New York: Wiley.

Brown, A. L., & Campione, J. C. (1994). Guided discovery in a community of learners. In K. McGilly (Ed.), *Classroom lessons: Integrating cognitive theory and classroom practice* (pp. 229-272). Cambridge, MA: MIT Press.

Brown, A. L., & Campione, J. C. (1996). Psychological theory and the design of innovative learning environments: On procedures, principles, and systems. In L. Schauble & R. Glaser (Eds.), *Innovations in learning: New environments for education* (pp. 289-325). Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, J. S., Collins, A. & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18, 32-42.

Bruer, J. T. (1993). *Schools for thought: A science of learning in the classroom*. Cambridge, MA: MIT Press.

Bruer, J. T. (1997). Education and the brain: A bridge too far. *Educational Researcher*, 26, 4-16.

Bruer, J. T. (1999). *The myth of the first three years: A new understanding of early brain development and lifelong learning*. New York: The Free Press.

Bruner, J. (1960). *The process of education*. Cambridge, MA: Harvard University Press.

Bruner, J. (1990). *Acts of meaning*. Cambridge, MA: Harvard University Press.

Bryan, W. L., & Harter, N. (1897). Studies in the physiology and psychology of the telegraphic language. *Psychological Review*, 4, 27-53.

Burnham, D., Kitamura, C., & Vollmer-Conna, U. (2002). What's new, pussycat? On talking to babies and animals. *Science*, 296, 1435.

Buchner, A., Erdfelder, E., Steffens, M. C., & Martensen, H. (1997). The nature of memory processes underlying recognition judgments in the process dissociation procedure. *Memory & Cognition*, 25, 508-517.

Cadiz, J.J., Balachandran, A., Sanocki, E., Gupta, A., Grudin, J., & Jancke, G. (2000). *Distance learning through distributed collaborative video viewing*. Proceedings of the 2000 ACM conference on Computer Supported Cooperative Work (CSCW) (pp. 135-144). Philadelphia, PA.

Calfee, R., & Berliner, D. (1996). Introduction to a dynamic and relevant psychology. In R. Calfee & D. Berliner (Eds.) *Handbook of educational psychology* (pp. 1-11). New York: MacMillan.

Callan, D. E., Jones, J. A., Callan, A. M., & Akahane-Yamada, R. (2004). Phonetic perceptual identification by native- and second-language speakers differentially activates brain regions involved with acoustic phonetic processing and those involved with articulatory-auditory/orosensory internal models. *NeuroImage*, 22, 1182-1194.

Carey, S. (2000). Science education as conceptual change. *Journal of Applied Developmental Psychology*, 21, 13-19.

Carraher, T. N., Carraher, D. W., & Schliemann, A. D. (1985). Mathematics in the streets and in schools. *British Journal of Developmental Psychology*, 3, 21-29.

Carraher, D.W. & Schliemann, A.D. (2002). The transfer dilemma. *Journal of the Learning Sciences*, 11, 1-24.

Chang, C. (2002). Self-congruency as a cue in different advertising-processing contexts. *Communication Research*, 29(5), 503-536.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, 1, 33-81.

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

Chi, M. T. H., Feltovich, P. & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science*, 5, 121-152.

Chi, M. T. H., Glaser, R., & Farr, M. (1988). *The nature of expertise*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence*, (Vol. 1, pp. 1-75). Hillsdale, NJ: Lawrence Erlbaum Associates.

Christensen, C.M. (1997). *The innovator's dilemma: When new technologies cause great firms to fail*. Cambridge, MA: Harvard Business School Press.

Cognition and Technology Group at Vanderbilt. (1997). *The Jasper Project: Lessons in curriculum, instruction, assessment, and professional development*. Mahwah, NJ: Lawrence Erlbaum Associates.

Cognition and Technology Group at Vanderbilt (2000). Adventures in anchored instruction: Lessons from beyond the ivory tower. In R. Glaser (Ed.), *Advances in instructional psychology: Educational design and cognitive science*, (Vol. 5, pp. 35-100). Mahwah, NJ: Lawrence Erlbaum Associates.

Cole, M. (1996). *Cultural psychology: A once and future discipline*. Cambridge, MA: Harvard University Press.

Cole, M., & Bruner, J. S. (1971). Cultural differences and inferences about psychological processes. *American Psychologist*, 26, 867-876.

Cole, M., Engeström, Y., & Vasquez, O (1997). Introduction. In M. Cole, Y. Engeström, & O. Vasquez (Eds.), *Mind, culture and activity*. Cambridge: Cambridge University Press.

Cole, M., Hood, L., & McDermott, R. (1978). *Ecological niche picking: Ecological invalidity as an axiom of experimental cognitive psychology*. New York: Rockefeller University, Laboratory of Comparative Human Cognition and Institute for Comparative Human Development.

Cole, M., Hood, L., & McDermott, R. (1997). Concepts of ecological validity: Their differing implications for comparative cognitive research. In M. Cole, Y. Engeström & O. Vasquez (Eds.), *Mind, culture, and activity: Seminal papers from the Laboratory of Comparative Human Cognition* (pp. 49-56). New York: Cambridge University Press.

Coleman, E. (1998). Using explanatory knowledge during collaborative problem solving in science. *Journal of Learning Sciences*, 7, 387-427.

Collins, A. (1992). Toward a design science of education. In E. Scanlon and T. O'Shea (Eds.), *New directions in educational technology* (pp. 15-22). New York: Springer-Verlag.

Crawford, V., Riel, M., & Schlager, M. (2005). *Characterizing adaptive expertise in biology teachers' reasoning*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Cronbach, L. J. (1975). Beyond the two disciplines of scientific psychology. *American Psychologist*, 30, 116-127.

Cronbach, L. J., & Meehl, P.E. (1955). Construct validity in psychological tests. *Psychological Bulletin*, 52, 281-302.

Crowley, K., & Jacobs, M. (2002). Building islands of expertise in everyday family activity. In G. Leinhardt, K. Crowley & K. Knutson (Eds.), *Learning conversations in museums* (pp. 333-356). Mahwah, NJ: Lawrence Erlbaum Associates.

Darling-Hammond, L., & Bransford, J. (Eds.). (2005). *Preparing teachers for a changing world*. San Francisco: Jossey-Bass.

Das, V. (1998). Wittgenstein and Anthropology. *Annual Review of Anthropology*, 27, 171-195.

deAbreu, G. (1995). Understanding how children experience the relationship between home and school mathematics. *Mind, Culture, and Activity*, 2(3), 119-142.

deGroot, A. D. (1965). *Thought and choice in chess*. The Hague, the Netherlands: Mouton.

Decety, J., Jackson, P. L., Sommerville, J., Chaminade, T., & Meltzoff, A. N., (2004). The neural bases of cooperation and competition: an fMRI investigation. *NeuroImage*, 23, 744-751.

Dehaene, S., & Changeux, J.-P. (1997). A hierarchical neuronal network for planning behavior. *Proceedings of the National Academy of Sciences*, 94, 13293-13296.

DeSchepper, B., & Treisman, A. 1996. Visual memory for novel shapes: Implicit coding without attention. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 22, 27-47.

Design-Based Research Collective (DBRC). (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8.

Detterman, D. K., & Sternberg, R. J. (1993). *Transfer on trial: Intelligence, cognition and instruction*. Norwood, NJ: Ablex.

Diller, K. R., Roselli, R., & Martin, T. (2004). *Teaching biotransport based on "How People Learn" motivated methodology*. Proceedings of 2004 American Society of Mechanical Engineers International Mechanical Engineering Congress, Anaheim, CA.

diSessa, A. A. (1982). Unlearning Aristotelian physics: A study of knowledge-based learning. *Cognitive Science*, 6, 37-75.

Donovan, M. S. & Bransford, J. D. (2005). Introduction. In National Research Council, *How students learn* (pp. 1-28). Washington, DC: National Academy Press.

Driver, R., Guesne, E., & Tiberghien, A. (Eds.). (1985). *Children's ideas in science*. Philadelphia: Open University Press.

Dufresne, R. J., Gerace, W. J., Leonard, W. J., Mestre, J. P., & Wenk, L. (1996). Classtalk: A classroom communication system for active learning. *Journal of Computing in Higher Education*, 7, 3-47.

Eckert, P. (1989). *Jocks and burnouts: Social categories and identity in the high school*. New York: Teachers College Press.

Elkind, D. (2001). *The burried child: Growing up too fast too soon* (3rd ed.). Cambridge, MA: Perseus.

Emerson, R. (2001). *Contemporary field research: Perspectives and formulations*. Prospect Heights: Waveland Press.

Engelmann, S. (1992). *War against the school's academic child abuse*. Portland, OR: Halcyon, House.

Engeström, Y., Brown, K., Christopher, L., & Gregory, J. (1997). Coordination, cooperation, and communication in the courts: Expansive transitions in legal work. In M. Cole, Y. Engeström & O. Vasquez (Eds.), *Mind, culture, and activity: Seminal papers from the Laboratory of Comparative Human Cognition* (pp. 369-385). New York: Cambridge University Press.

Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock (Ed.), *Handbook of research on teaching*. New York: MacMillan.

Feuerstein, R., Rand, Y., & Hoffman, M. (1979). *The dynamic assessment of retarded performers: The learning potential assessment device, theory, instruments, and techniques*. Baltimore, MD: University Park Press.

Flavell, J. H., & Miller, P. H. (1998). Social cognition. In W. Damon (Series Ed.) D. Kuhn & R. Siegler (Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 851-898). New York: Wiley.

Fromkin, V., Krashen, S., Curtis, S., Rigler, D., & Rigler, M. (1974). The development of language in Genie: A case of language acquisition beyond the "critical period." *Brain & Language*, 1, 81-107.

Fullan, M. (2001). *Leading in a culture of change*. San Francisco: Wiley.

Fullan, M. (2003). *Change forces with a vengeance*. London: RoutledgeFalmer.

Gee, J. P. (2003a). *What video games have to teach us about learning and literacy*. New York: Palgrave.

Gee, J. P. (2003b). *Learning about learning from a video game: Rise of nations*. University of Wisconsin-Madison.

Gentner, D., Brem, S., Ferguson, R. W., Markman, A. B., Levidow, B. B., Wolff, P., et al. (1997). Analogical reasoning and conceptual change: A case study of Johannes Kepler. *Journal of the Learning Sciences*, 6(1), 3-40.

Gibbons, J. F., Kincheloe, W. R., & Down, K. S. (1977, March). Tutored videotape instruction: a new use of electronics media in education. *Science*, 1139-1146.

Gick, M. L., & Holyoak, K. J. (1980). Analogical problem solving. *Cognitive Psychology*, 12, 306-365.

Gick, M. L., & Holyoak, K. J. (1983). Schema induction and analogical transfer. *Cognitive Psychology*, 15, 1-38.

Glascott, J. (2001). Gender roles on prime-time network television: Demographics and behaviors. *Journal of Broadcasting & Electronic Media*, 45(4), 665-669.

Golestani, N., & Zatorre, R. J. (2004). Learning new sounds of speech: reallocation of neural substrates. *NeuroImage*, 21, 494-506.

González, N., Moll, L. C., & Amanti, C. (2005). *Theorizing education practice: Funds of knowledge in households*. Mahwah, NJ: Lawrence Erlbaum Associates.

Goodsitt, J., Morgan, I., & Kuhl, P. (1993). Perceptual strategies in prelingual speech segmentation. *Journal of Child Language*, 20, 229-252.

Goodwin, C. (1992). Rethinking context: an introduction. In A. Duranti & C. Goodwin (Eds.), *Rethinking context: Language as an interactive phenomenon*. Cambridge: Cambridge University Press.

Goodwin, C. (2000). Action and embodiment within situated human interaction. *Journal of Pragmatics*, 32, 1489-1522.

Gopnik, A., & Meltzoff, A. N. (1997). *Words, thoughts, and theories*. Cambridge, MA: MIT Press.

Gopnik, A., Meltzoff, A. N., & Kuhl, P. K. (1999). *The scientist in the crib: Minds, brains, and how children learn*. New York: William Morrow.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 11, 501-518.

Greeno, J., Collins, A., & Resnick, L. (1996). Cognition and learning. In R. Calfee & D. Berliner (Eds.), *Handbook of educational psychology* (pp. 15-46). New York: MacMillan.

Greenough, W. T., Black, J. E., & Wallace, C. S. (1987). Experience and brain development. *Child Development*, 58, 539-559.

Greenough, W. T., Juraska, J. M., & Volkmar, F. (1979). Maze training effects on dendritic branching in occipital cortex of adult rats. *Behavioral and Neural Biology*, 26, 287-297.

Greenwald, A. G., & Banaji, M. R. (1995). Implicit social cognition: Attitudes, self-esteem, and stereotypes. *Psychological Review*, 102, 4-27.

Greenwald, A. G., Banaji, M. R., Rudman, L. A., Farnham, S. D., Nosek, B. A., & Mellott, D. S. (2002). A unified theory of

implicit attitudes, stereotypes, self-esteem, and self-concept. *Psychological Review*, 109, 3–25.

Grossman, P., Schoenfeld, A., & Lee, C. (2005). Teaching subject matter. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world* (pp. 201–231). San Francisco: Jossey-Bass.

Guenther, F. H., Nieto-Castanon, A., Ghosh, S. S., & Tourville, J. A. (2004). Representation of sound categories in auditory cortical maps. *Journal of Speech, Language, and Hearing Research*, 47, 46–57.

Gutierrez, K. (2005). *Revisiting the continuity/discontinuity narrative: How schools reorganize the everyday routines of middleclass working families*. Working Paper. Center for the Everyday Lives of working Families, UCLA.

Hall, R., & Stevens, R. (1995). Making space: A comparison of mathematical work at school and in professional design practice. In S. L. Star (Ed.), *Cultures of computing* (pp. 118–145). London: Basil Blackwell.

Hall, R., Stevens, R., & Torralba, A. (2002). Disrupting representational infrastructure in conversations across disciplines. *Mind, Culture, and Activity*, 9(3), 179–210.

Hanna, E., & Meltzoff, A. N. (1993). Peer imitation by toddlers in laboratory, home, and day-care contexts: Implications for social learning and memory. *Developmental Psychology*, 29, 701–710.

Harris, T. R., Bransford, J. D., and Brophy, S. P. (2002). Roles for learning sciences and learning technologies in biomedical engineering education: A review of recent advances. *Annual Review of Biomedical Engineering*, 4, 29–48.

Hatano, G. (2005). *Adaptive expertise*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.), *Child development and education in Japan* (pp. 262–272). New York: Freeman.

Hatano, G., & Inagaki, K. (1991). Sharing cognition through collective comprehension activity. In L. B. Resnick, J. Levine, & S. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 331–348). Washington, DC: American Psychological Association.

Hatano, G., & Osuro, Y. (2003). Commentary: Reconceptualizing school learning using insight from expertise research. *Educational Researcher*, 32, 26–29.

Healy, J. M. (1991). *Endangered minds: Why children don't think and what we can do about it*. New York: Simon & Schuster.

Heath, S. B. (1983). *Ways with words: Language, life, and work in communities and classrooms*. New York: Cambridge University Press.

Heath, S. B. (2001). Three's not a crowd: Plans, roles, and focus in the arts. *Educational Researcher*, 30(7), 10–17.

Hendrickson, G., & Schroder, W.H. (1941). Transfer of training in learning to hit a submerged target. *Journal of Educational Psychology*, 32, 205–213.

Hestenes, D. (1987). Toward a modeling theory of physics instruction. *American Journal of Physics*, 55, 440–454.

Hodge, L., & Brophy, S. (2005). *How is identify relevant to the notion of adaptive expertise?* Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Holland, D., Lachicotte, W., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.

Holt, J. (1964). *How children fail*. New York, NY: Dell.

Hong, H., & Lin, X. D. (2005). *Effect of people knowledge on science learning*. Paper presented at the meeting of the American Educational Research Association, Montreal, Canada.

Howard, D. V., & Howard, J. H., Jr. (2001). When it does hurt to try: Adult age differences in the effects of instructions on sequential pattern learning. *Psychonomic Bulletin and Review*, 8(4), 798–805.

Hurley, S., & Chater, N. (Eds.). (2005). *Perspectives on imitation: From cognitive neuroscience to social science* (Vols. 1 & 2). Cambridge, MA: MIT Press.

Hutchins, E. (1993). Learning to navigate. In S. Chaiklin & J. Lave (Eds.), *Understanding practice: Perspectives on activity and context* (pp. 35–63). Cambridge: Cambridge University Press.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *Journal of Comparative Neurology*, 387, 167–178.

Iverson, P., Kuhl, P. K., Akahane-Yamasa, R., Diesch, E., Tohkura, Y., Kettermann, A., & Siebert, C. (2003). A perceptual interference account of acquisition difficulties for non-native phonemes. *Cognition*, 87, B47–B57.

Invernizzi, F., Falomir, P., Manuel, J., Muñoz, R. D., & Mugny, G. (2003). Social influence in personally relevant contexts: The respect attributed to the source as a factor increasing smokers' intention to quit smoking. *Journal of Applied Social Psychology*, 33(9), 1818–1836.

Iyengar, S., & Kinder, D. R. (1987). *News that matters: Television and American opinion*. Chicago: University of Chicago Press.

Iyengar, S., & Simon, A. F. (1993). News coverage of the Gulf War and public opinion: A study of agenda-setting, priming, and framing. *Communication Research*, 20, 365–383.

Jackson, P. L., Meltzoff, A. N., & Decety, J. (2005). How do we perceive the pain of others? A window into the neural processes involved in empathy. *NeuroImage*, 24, 771–779.

Jacoby, S., & Gonzales, P. (1991). The constitution of expert novice in scientific discourse. *Issues in Applied Linguistics*, 2, 150–181.

Jessor, R., Colby, A., & Shweder, R. A. (Eds.). (1996). *Ethnography and human development*. Chicago: University of Chicago Press.

Johnson, D., & Johnson, R. (1981). Effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychological Bulletin*, 89(1), 47–62.

Judd, C. H. (1908). The relation of special training to general intelligence. *Educational Review*, 36, 28–42.

Karmiloff-Smith, A., & Inhelder, B. (1974). "If you want to get ahead, get a theory," *Cognition*, 3(3), 195-212.

Katz, J. (2001). From how to why: On luminous description and causal inference in ethnography (Part I). *Ethnography*, 2(4), 1466-1381.

King, A. (1990). Facilitating elaborative learning in the classroom through reciprocal questioning. *American Educational Research Journal*, 27, 664-687.

Krosnick, J. A., & Branon, L. A. (1993). The impact of the Gulf War on the ingredients of presidential evaluations: Multidimensional effects of political involvement. *American Political Science Review*, 87, 963-978.

Kuhl, P. K. (1991). Human adults and human infants show a "perceptual magnet effect" for the prototypes of speech categories, monkeys do not. *Perception & Psychophysics*, 50, 93-107.

Kuhl, P. K. (2000). A new view of language acquisition. *Proc National Academy of Science, USA*, 97, 11850-11857.

Kuhl, P. K. (2003). Human speech and birdsong: Communication and the social brain. *Proceedings of the National Academy of Sciences*, 100, 9645-9646.

Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience*, 5, 831-843.

Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., et al. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science*, 277, 684-686.

Kuhl, P. K., Conboy, B. T., Padden, D., Nelson, T. and Pruitt, J. (2005). Early speech perception and later language development: Implications for the "critical period." *Language Learning and Development*, 1, 237-264.

Kuhl, P. K., & Meltzoff, A. N. (1982). The bimodal perception of speech in infancy. *Science*, 218, 1138-1141.

Kuhl, P. K., Tsao, F.-M., & Liu, H.-M. (2003). Foreign-language experience in infancy: Effects of short-term exposure and social interaction on phonetic learning. *Proceedings of the National Academy of Sciences*, 100, 9096-9101.

Kuhl, P. K., Williams, K. A., Lacerda, F., Stevens, K. N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, 255, 606-608.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

LaBerge, D. & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 6, 293-323.

Labov, W. (1969). The logic of nonstandard English. *Georgetown Monographs on Language and Linguistics*, 22, 1-31.

Labov, W. (1972). *Language in the inner city: Studies in the Black English vernacular*. Philadelphia: University of Pennsylvania Press.

Lajoie, S. (2003). Transitions and trajectories for studies of expertise. *Educational Researcher*, 32, 21-25.

Larson, M. S. (2001). Sibling interaction in situation comedies over the years. In Bryant, Jennings & J. A. Bryant (Eds.), *Television and the American family* (pp. 163-176). Mahwah, NJ: Lawrence Erlbaum Associates.

Latour, B. (1995). The "pedofil" of Boa Vista: A philosophical montage. *Common Knowledge*, 4(1), 144-187.

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. New York: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. New York: Cambridge University Press.

Lee, C. D. (1995). A culturally based cognitive apprenticeship: Teaching African American high school students skills in literary interpretation. *Reading Research Quarterly*, 30(4), 608-631.

Lemke, J. L. (2001). The long and the short of it: Comments on multiple time-scale studies of human activity. *The Journal of the Learning Sciences*, 10, 17-26.

Leont'ev, A. N. (1978). *Activity, consciousness, and personality*. Englewood Cliffs, NJ: Prentice-Hall.

Lin, X. D., & Bransford, J. (2005). *People knowledge: A useful ingredient for bridging cultural differences between teachers and students*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Lin, X. D., & Lehman, J. (1999). Supporting learning of variable control in a computer-based biology environment: Effects of prompting college students to reflect on their own thinking. *Journal of Research in Science Teaching*, 36(7), 837-858.

Linn, M. C., Davis, E. A., & Bell, P. (2004). *Internet environments for science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Liu, H.-M., Kuhl, P. K., & Tsao, F.-M. (2003). An association between mothers' speech clarity and infants' speech discrimination skills. *Developmental Science*, 6, F1-F10.

Lockhart, R. S., Lamon, M., & Gick, M. L. (1988). Conceptual transfer in simple insight problems. *Memory and Cognition*, 16, 36-44.

Loftus, E. F., & Loftus, G. R. (1974). Changes in memory structure and retrieval over the course of instruction. *Journal of Educational Psychology*, 66(3), 315-318.

Luria, A. R. (1976). *Cognitive development: Its cultural and social foundations*. Cambridge, MA: Harvard University Press.

MacWhinney, B., Bird, S., Cieri, C., & Martell, C. (2004). *Talk-Bank: Building an open unified multimodal database of communicative interaction*. LREC 2004, Lisbon.

Magnusson, S., & Palinscar, A. (2005). Teaching to promote the development of scientific knowledge and reasoning about light at the elementary level. In National Research Council, *How students learn: History, science, mathematics and science in the classroom* (pp. 421-459). Washington, DC: National Academy Press.

Martin, T. (2005). *Measuring preparation for future learning in children's mathematics: Instructional implications*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Martin, T., & Schwartz, D. L. (2005). Physically distributed learning: Adapting and reinterpreting physical environments in the development of fraction concepts. *Cognitive Science*, 29, 587-625.

Matusov, E., Bell, N., & Rogoff, B. (2002). Schooling as a cultural process: Shared thinking and guidance by children from schools differing in collaborative practices. In R. Kail & H. Reese, (Eds.) *Advances in Child Development and Behavior*, 29. San Diego, CA: Academic Press, Inc.

Mayer, R., & Wittrock, M. (1996). Problem-solving transfer. In R. Calfee, & D. Berliner (Eds.) *Handbook of educational psychology* (pp. 47-62). New York: MacMillan.

Mayer, R. E., Fennell, S., Lindsay, F., & Campbell, J. (2004). A personalization effect in multimedia learning: Students learn better when words are in conversational style rather than formal style. *Journal of Educational Psychology*, 96(2), 389-395.

McCandliss, B. D., Fiez, J. A., Protopapas, A., Conway, M., & McClelland, J. (2002). Success and failure in teaching the [r]-[l] contrast to Japanese adults: tests of a Hebbian model of plasticity and stabilization in spoken language perception. *Cognitive, Affective, and Behavioral Neuroscience*, 2, 89-108.

McClelland, J. L. (2001). Failures to learn and their remediation: A Hebbian account. In J. L. McClelland and R. S. Siegler (Eds.), *Mechanisms of cognitive development: Behavioral and neural perspectives*, (pp. 97-121). Mahwah, NJ: Lawrence Erlbaum Associates.

McClelland, J. L., Fiez, J. A., & McCandliss, B. D. (2002). Teaching the /r/-/l/ discrimination to Japanese adults: Behavioral and neural aspects. *Physiology & Behavior*, 77, 657-662.

McCloskey, M. (1983). Intuitive physics. *Scientific American*, 284(4).

McDermott, R. (2001). A century of Margaret Mead. *Teacher's College Record*, 103(5), 843-867.

McDermott, R. P., Goldman, S. V., & Varenne, H. (1984). When school goes home: Some problems in the organization of homework. *Teachers College Record*, 85, 391-409.

Mead, M. (1928). *Coming of age in Samoa: A psychological study of primitive youth for western civilization*. New York: William Morrow.

Meltzoff, A. N. (1988a). Imitation of televised models by infants. *Child Development*, 59, 1221-1229.

Meltzoff, A. N. (1988b). Imitation, objects, tools, and the rudiments of language in human ontogeny. *Human Evolution*, 3, 45-64.

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, 31, 838-850.

Meltzoff, A. N. (2005). Imitation and other minds: The "like me" hypothesis. In S. Hurley & N. Chater (Eds.), *Perspectives on imitation: From neuroscience to social science* (Vol. 2, pp. 55-77). Cambridge, MA: MIT Press.

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society of London: Biological Sciences*, 358, 491-500.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, 198, 75-78.

Meltzoff, A. N., & Prinz, W. (Eds.). (2002). *The imitative mind: Development, evolution and brain bases*. Cambridge: Cambridge University Press.

Merzenich, M. M., Jenkins, W. M., Johnston, P., Schreiner, C., Miller, S. L., & Tallal, P. (1996). Temporal processing deficits of language-learning impaired children ameliorated by training. *Science*, 271, 77-81.

Mestre, J. P. (1994, February). Cognitive aspects of learning and teaching science. In S.J. Fitzsimmons & L.C. Kerpelman (Eds.), *Teacher Enhancement for Elementary and Secondary Science and Mathematics: Status, Issues and Problems* (pp. 31-53). Washington, DC: National Science Foundation (NSF 94-80).

Mestre, J. P., Thaden-Koch, T. C., Dufresne, R. J., & Gerace, W. J. (in press). The dependence of knowledge deployment on context among physics novices. In E. Redish & M. Vicentini (Eds.), *Proceedings of the International School of Physics "Enrico Fermi", Course CLVI, Research on Physics Education*. Amsterdam: IOS Press.

Michael, A. L., Klee, T., Bransford, J. D., & Warren, S. (1993). The transition from theory to therapy: Test of two instructional methods. *Applied Cognitive Psychology*, 7, 139-154.

Miell, D., & MacDonald, R.A.R. (2000). Children's creative collaborations: The importance of friendship when working together on a musical composition. *Social Development*, 9, 348-369.

Minstrell, J. (2005). *Facets of student thinking: A classroom assessment framework*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Miyawaki, K., Strange, W., Verbrugge, R., Liberman, A. M., Jenkins, J. J., & Fujimura, O. (1975). An effect of linguistic experience: The discrimination of [r] and [l] by native speakers of Japanese and English. *Perception & Psychophysics*, 18, 331-340.

Mutz, D. C., & Reeves, B. (in press). Exposure to mediated political conflict: Effects of civility of interaction on arousal and memory. *American Political Science Quarterly*.

Näätänen, R., Lehtokoski, A., Lennes, M., Cheour, M., Huotilainen, M., Iivonen, A., et al. (1997). Language-specific phoneme representations revealed by electric and magnetic brain responses. *Nature*, 385, 432-434.

Nasir, N. S. (2002). Identity, goals, and learning: mathematics in cultural practice. *Mathematical Thinking and Learning*, 4(2 & 3), 213-247.

Nathan, M. J., Koedinger, K. R., & Alibali, M. W. (2001). "Expert blind spot: when content knowledge eclipses pedagogical content knowledge." In L. Chen et al. (Eds.), *Proceeding of the Third International Conference on Cognitive Science*. (pp. 644-648). Beijing, China: USTC Press.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics (1995). *Assessment standards for school mathematics*. Reston, VA: NCTM.

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics*. Reston, VA: NCTM.

National Research Council (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council (1999). *Being fluent with information technology*. Washington, DC: National Academy Press.

National Research Council (2000). *How people learn: Brain, mind, experience, and school* (Expanded Edition). Washington, DC: National Academy Press. [On-line]. Available: <http://www.nap.edu/html/howpeople1/>

National Research Council (2001). *Knowing what students know: The science and design of educational assessment*. Washington, DC: National Academy Press.

National Research Council (2002). *Learning and understanding: Improving advanced study of mathematics and science in U.S. high schools*. Washington, DC: National Academy Press.

National Research Council (2003). *Learning and instruction: A SERP research agenda*. Washington, DC: National Academy Press.

National Research Council (2005). *How students learn: History, math, and science in the classroom*. Washington, DC: National Academies Press.

Newell, K., Liu, Y., & Mayer-Kress, G. (2001). Time scales in motor learning and development. *Psychological Review*, 108, 57-82.

Nielsen, A. C. (1987). *Annual Nielsen report on television: 1987*. Nielsen Media Research, New York.

Neisser, U. (1976). *Cognition and reality*. San Francisco: Freeman.

Newport, E.L. and Aslin, R.N. (2004). Learning at a distance I. Statistical learning of non-adjacent dependencies. *Cognitive Psychology*, 48, 127-162.

Nissen, M. J., & Bullemer, P. T. (1987). Attentional requirements for learning: Evidence from performance measures. *Cognitive Psychology*, 19, 1-32.

Norman, D. A. (1993). *Things that make us smart: Defending human attributes in the age of the machine*. New York: Addison-Wesley.

Ochs, E., Taylor, C., Rudolph, D., & Smith, R. (1992). Storytelling as a theory-building activity. *Discourse Processes*, 15(1), 37-17.

Ochsner, K. N., & Lieberman, M. D. (2001). The emergence of social cognitive neuroscience. *American Psychologist*, 56, 717-734.

Palincsar, A. S. & Brown, A. L. (1989). Instruction for self-regulated reading. In L. B. Resnick & L. E. Klopfer (Eds.), *Toward the thinking curriculum: Current cognitive research* (pp. 19-39). Alexandria, VA: ASCD.

Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. New York: Basic Books.

Pea, R. D. (1987). Socializing the knowledge transfer problem. *International Journal of Educational Research*, 11, 639-663.

Pea, R. D. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.). *Distributed cognitions*. New York: Cambridge University Press, pp. 47-87.

Pea, R. D. (in press). Video-as-data and digital video manipulation techniques for transforming learning sciences research, education and other cultural practices. To appear in J. Weiss, J. Nolan & P. Trifonas (Eds.), *International Handbook of Virtual Learning Environments*. Dordrecht: Kluwer Academic Publishing.

Pea, R., Mills, M., Rosen, J., Dauber, K., Effelsberg, W., & Hofert, E. (2004, Jan-March). The DIVER™ Project: Interactive Digital Video Repurposing. *IEEE Multimedia*, 11(1), 54-61.

Penuel, W. R., & Yarnall, L. (2005). Designing handheld software to support classroom assessment: An analysis of conditions for teacher adoption. *Journal of Technology, Learning, and Assessment*, 3(5), Available from <http://www.jtla.org>.

Petrosino, A. (2005). *Measures of adaptive expertise in bioengineering*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Petty, R. E., Priester, J. R., & Briñol, P. (2002). Mass media attitude change: Implications of the elaboration likelihood model of persuasion. In Bryant, J. & D. Zillman (Eds.), *Media effects: Advances in theory and research* (pp. 155-198). Mahwah, NJ: Lawrence Erlbaum Associates.

Phelps, E., & Damon, W. (1989). Problem solving with equals: Peer collaboration as a context for learning mathematics and spatial concepts. *Journal of Educational Psychology*, 81(4), 639-646.

Philips, S. (1983). *The invisible culture: Communication in classroom and community on the Warm Springs Indian Reservation*. Prospect Heights, IL: Waveland Press, Inc.

Piaget, J. (1952). *The origins of intelligence in children*. (M. Cook, Trans) New York: International Universities Press.

Piaget, J. (1964). Development and learning. In R. E. Ripple & V. N. Rockcastle. (Eds.). *Piaget rediscovered*. New York: Cornell University Press.

Pisoni, D. B. (1993). Long-term memory in speech perception: Some new findings on talker variability, speaking rate and perceptual learning. *Speech Communication*, 13, 109-125.

Pisoni, D., Aslin, R., Perey, A., & Hennessy, B. (1994). Perceptual learning of normative speech contrasts: Implications for theories of speech perception. In J. Goodman & H. Nusbaum (Eds.), *The development of speech perception: The transition from speech sounds to spoken words* (pp. 121-166). Cambridge, MA, USA: The MIT Press.

Polanyi, M. (1958). *Personal knowledge: Towards a post-critical philosophy*. London: Routledge.

Polanyi, M. (1967). *The tacit dimension*. New York: Anchor Books.

Poldrack, R. A. (2000). Imaging brain plasticity: Conceptual and methodological issues. *NeuroImage*, 12, 1-13.

Poldrack, R. A., Clark, J., Pare-Blaogev, J., Shohamy, D., Crespo Moyano, J., Myers, C., et al. (2001). Interactive memory systems in the human brain. *Nature*, 414, 546-550.

Povinelli, D. J., Reaux, J. E., Theall, L. A., & Giambrone, S. (2000). *Folk physics for apes: The chimpanzee's theory of how the world works*. New York: Oxford University Press.

Pressley, M. (1995). More about the development of self-regulation: Complex, long-term, and thoroughly social. *Educational Psychologist*, 30(4), 207-212.

Reber, A. S. (1967). Implicit learning of artificial grammars. *Journal of Verbal Learning and Verbal Behavior, 6*, 855-863.

Reber, A. S. (1976). Implicit learning of synthetic languages: The role of instructional set. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 88-94.

Reber, A. S. (1993). *Implicit learning and tacit knowledge: An essay on the cognitive unconscious*. New York: Oxford University Press.

Resnick, L. (1987). Learning in school and out. *Educational Researcher, 16*(9), 13-20.

Rideout, V. J., Vandewater, E., & Wartella, E. A. (2003, Fall). *Zero to six: Electronic media in the lives of infants, toddlers and preschoolers*. Kaiser Family Foundation Report.

Rizzolatti, G., Fadiga, L., Fogassi, L., & Gallese, V. (2002). From mirror neurons to imitation, facts, and speculations. In A. N. Meltzoff & W. Prinz (Eds.), *The imitative mind: Development, evolution, and brain bases* (pp. 247-266). Cambridge: Cambridge University Press.

Rizzolatti, G., Fadiga, L., Gallese, V., & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Cognitive Brain Research, 3*, 131-141.

Robinson, A., & Stern, S. (1997). Corporate creativity: How innovation and improvement actually happen. San Francisco: Berrett-Koehler.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context*. New York: Oxford University Press.

Rogoff, B. (1995). Observing sociocultural activity on three planes: participatory appropriation, guided participation, and apprenticeship. In J. Wertsch, P. del Río, & A. Alvarez. (Eds.) *Sociocultural studies of mind*. New York: Cambridge University Press.

Rogoff, B. (2003). *The cultural nature of human development*. New York: Oxford University Press.

Rogoff, B., & Lave, J. (1984). *Everyday cognition: Its development in social context*. Cambridge, MA: Harvard University Press.

Rogoff, B., Matusov, E., & White, C. (1996). Models of teaching and learning: Participation in a community of learners. In D. Olson & N. Torrance (Eds.), *Handbook of education and human development: New models of learning, teaching, and schooling* (pp. 388-414). London: Basil Blackwell.

Rogoff, B., Paradise, R., Mejía Arauz, R., Correa-Chávez, M., & Angelillo, C. (2003). Firsthand learning by intent participation. *Annual Review of Psychology, 54*.

Rose, M. (2004). *The mind at work: Valuing the intelligence of the American worker*. New York: Viking.

Saffran, J. R. (2002). Constraints on statistical language learning. *Journal of Memory and Language, 47*, 172-196.

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. *Current Directions in Psychological Science, 12*, 110-114.

Salomon, G., & Perkins, D. (1989). Rocky road to transfer: Rethinking mechanisms of a neglected phenomenon. *Educational Psychologist, 24*, 113-142.

Saxe, G. B. (1982). Developing forms of arithmetic operations among the Oksapmin of Papua New Guinea. *Developmental Psychology, 18*(4), 583-594.

Schacter, D. L. (1987). Implicit memory: History and current status. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*(3), 501-518.

Schank R., & Abelson R. (1977). *Scripts, plans, goals and understanding: An inquiry into human knowledge structures*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schegloff, E. A. (1992). On talk and its institutional occasions. In P. Drew & J. Heritage (Eds.), *Talk at work* (pp. 101-134). New York: Cambridge University Press.

Schleuder, J., McCombs, M., & Wanta, W. (1991). Inside the agenda-setting process: How political advertising and TV news prime viewers to think about issues and candidates. In F. Biocca (Ed.), *Television and political advertising 1: Psychological processes* (pp. 263-310). Hillsdale, NJ: Lawrence Erlbaum Associates.

Schliemann, A. D., & Acioly, N. M. (1989). Mathematical knowledge developed at work: The contribution of practice versus the contribution of schooling. *Cognition & Instruction, 6*, 185-222.

Schmuckler, M. A. (2001). What is ecological validity? A dimensional analysis. *Infancy, 2*(4), 419-436.

Schoenfeld, A. H. (1985). *Mathematical problem solving*. New York: Academic Press.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition and sense-making in mathematics. In D. Grouws (Ed.), *Handbook for research on mathematics teaching and learning*. New York: Macmillan.

Schwartz, D. L., & Bransford, J. D. (1998). A time for telling. *Cognition & Instruction, 16*(4), 475-522.

Schwartz, D. L., & Martin, T. (2004) Inventing to prepare for learning: The hidden efficiency of original student production in statistics instruction. *Cognition & Instruction, 22*, 129-184.

Schwartz, D., Bransford, J., & Sears, D. (2005). Efficiency and innovation in transfer. In J. Mestre (Ed.), *Transfer of learning: from a modern multidisciplinary perspective* (pp. 1-51). Greenwich, CT: Information Age Publishing.

Schwartz, D., Blair, K., Davis, J., Chang, J., & Hartman, K. (2005). *Iterative dynamic assessments with feedback to students*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Scribner, S. (1997a). Knowledge at work. In E. Tobach, R. J. Falmagne, M. B. Parlee, L. M. W. Martin & A. S. Kapelman (Eds.), *Mind & social practice: Selected writings of Sylvia Scribner* (pp. 308-318). Cambridge: Cambridge University Press.

Scribner, S. (1997b). Studying working intelligence. In E. Tobach, R. J. Falmagne, M. B. Parlee, L. M. W. Martin, & A. S. Kapelman (Eds.), *Mind and social practice: Selected writings of Sylvia Scribner* (pp. 338-366). Cambridge: Cambridge University Press.

Scribner, S., & Fahrmeir, E. (1982). *Practical and theoretical arithmetic: Some preliminary findings, industrial literacy*

project (Working Paper No. 3). New York: City University of New York, Graduate Center.

Seger, C. A. (1994). Implicit Learning. *Psychological Bulletin*, 115, 163-196.

Shanahan, J., & Morgan, M. (1999). *Television and its viewers: Cultivation theory and research*. Cambridge: Cambridge University Press.

Shaughnessy, M. F. (2002, December). An Interview with Henry L. Roediger III. *Educational Psychology Review*, 14(4), 395-411.

Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57, 1-22.

Simon, D. A., & Bjork, R. A. (2002). Models of performance in learning multisegment movement tasks: Consequences for acquisition, retention, and judgments of learning. *Journal of Experimental Psychology: Applied*, 8, 222-232.

Singer, J. L., & Singer, D. G. (1981). *Television, imagination, and aggression: A study of preschoolers*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Smith, J. P., diSessa, A. A., & Roschelle, J. (1993). Misconceptions reconceived: A constructivist analysis of knowledge in transition. *The Journal of the Learning Sciences*, 3(2), 115-163.

Snow, C. E. (1981). The uses of imitation. *Journal of Child Language*, 8, 205-212.

Snow, C. E. (1982). Are parents language teachers? In K. Borman (Ed.), *The social life of children in a changing society* (pp. 81-95). Hillsdale, NJ: Lawrence Erlbaum Associates.

Snow, C. E. (1983). Saying it again: The role of expanded and deferred imitations in language acquisition. In K. E. Nelson (Ed.), *Children's language* (Vol. 4, pp. 29-58). New York: Gardner Press.

Sparks, G. G., & Ogles, R. M. (1990). The difference between fear of victimization and the probability of being victimized: Implications for cultivation. *Journal of Broadcasting & Electronic Media*, 34(3), 351-358.

Spiro, K., & McCombs, M. (2004). Agenda-setting effects and attitude strength: Political figures during the 1996 presidential election. *Communication Research*, 31(1), 36-57.

Spiro, R. J., Vispoel, W. L., Schmitz, J., Samaratungavanan, A., & Boeger, A. (1987). Knowledge acquisition for application: Cognitive flexibility and transfer in complex content domains. In B. C. Britton & S. Glynn (Eds.), *Executive control processes in reading* (pp. 177-199). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stadler, M. A., & Frensch, P. A. (1998). *Handbook of implicit learning*. Thousand Oaks, CA: SAGE.

Stephenson (2000). *Language use in mathematics classrooms*. Unpublished doctoral dissertation, Stanford University.

Sternberg, R. (2003). What is an "expert student"? *Educational Researcher*, 32, 5-9.

Stevens, R. J., & Slavin, R. E. (1995). The cooperative elementary school: Effects on students' achievement, attitudes, and social relations. *American Educational Research Journal*, 32, 321-351.

Stevens, R. (2000a). Divisions of labor in school and in the workplace: Comparing computer and paper-supported activities across settings. *The Journal of the Learning Sciences*, 9(4), 373-401.

Stevens, R. (2000b). Who counts what as math: Emergent and assigned mathematical problems in a project-based classroom. In J. Boaler (Ed.), *Multiple perspectives on mathematics education* (pp. 105-144). New York: Elsevier.

Stevens, R. (in press). Capturing ideas in digital things: A new twist on the old problem of inert knowledge. In Goldman, R., Pea, R. D., Barron, B., & Derry, S. (Eds.). *Video research in the learning sciences*. Mahwah, NJ: Lawrence Erlbaum Associates.

Stevens, R., Cherry, G., & Fournier, J. (2001). Video Traces: Rich media annotations for teaching and learning. In G. Stahl (Ed.). *Proceedings of the Computer Supported Collaborative Learning Conference*. Mahwah, NJ: Lawrence Erlbaum Associates.

Stevens, R., & Hall, R. (1997). Seeing Tornado: How *Video Traces* mediate visitor understandings of (natural?) spectacles in a science museum, *Science Education*, 18(6), 735-748.

Stevens, R., & Hall, R. (1998). Disciplined perception: Learning to see in technoscience. In M. Lampert & M. L. Blunk (Eds.), *Talking mathematics in school: Studies of teaching and learning* (pp. 107-149). Cambridge: Cambridge University Press.

Stevens, R., & Toro-Martell, S. (in press). Leaving a trace: Digital Meta-exhibits for supporting visitors to represent and exchange their ideas about museum exhibits. *Journal of Museum Education*.

Stevens, R., Wineburg, S., Herrenkohl, L., & Bell, P. (in press). The comparative understanding of school subjects: Past, present and future. *Review of Educational Research*.

Strange, W. (1995). *Speech perception and linguistic experience: Issues in cross-language research*. Timonium, MD: York.

Suchman, L. (1995). Making work visible. *Communications of the ACM*, 38(9), 57-64.

Tallal, P., Miller, S. L., Bedi, G., Byma, G., Wang, X. Q., Nagarajan, S. S., et al. (1996). Language comprehension in language-learning impaired children improved with acoustically modified speech. *Science*, 271, 81-84.

Taylor, M. (1996). A theory of mind perspective on social cognitive development. In E. C. Carterette & M. P. Friedman (Series Eds.) R. Gelman & T. Au (Eds.), *Handbook of perception and cognition: Vol. 13. Perceptual and cognitive development* (pp. 283-329). New York: Academic Press.

Tobach, E., Falmagne, R., J., Parlee, M. B., Martin, L. M. W., Kapelman, A. S. (Eds.) (1997). *Mind and social practice: Selected writings of Sylvia Scribner*. New York: Cambridge University Press.

Tremblay, K., Kraus, N., & McGee, T. (1998). The time course of auditory perceptual learning: neurophysiological changes during speech-sound training. *NeuroReport*, 9, 3557-3560.

Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.

Tomasello, M., & Call, J. (1997). *Primate cognition*. New York: Oxford University Press.

Trappey C. (1996). A meta-analysis of consumer choice and subliminal advertising. *Psychology & Marketing, 13*(5), 517-530.

Tsao, F.-M., Liu, H.-M., & Kuhl, P. K. (2004). Speech perception in infancy predicts language development in the second year of life: A longitudinal study. *Child Development, 75*, 1067-1084.

Tyack, D., & Tobin, W. (1984). The grammar of schooling: Why has it been so hard to change? *American Educational Research Journal, 31*(3), 453-479.

Vaill, P. B. (1996). *Learning as a way of being: Strategies for survival in a world of permanent white water*. San Francisco: Jossey-Bass.

Valdes, G., Bunch, G., Snow, C., Lee, C., & Matos, L. (2005). Enhancing the development of students' language. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world* (pp. 126-168). San Francisco: Jossey-Bass.

Van Lehn, K. (1990). *Mind bugs: The origins of procedural misconceptions*. Cambridge, MA: MIT Press.

Vera, A. H., & Simon, H. A. (1993). Situated action: A symbolic interpretation. *Cognitive Science, 17*, 7-48.

Vye, N. J., Schwartz, D. L., Bransford, J. D., Barron, B. J., Zech, L., & Cognition and Technology Group at Vanderbilt. (1998). SMART environments that support monitoring, reflection, and revision. In D. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *Metacognition in educational theory and practice* (pp. 305-346). Mahwah, NJ: Lawrence Erlbaum Associates.

Vygotsky, L. S. (1962). *Thought and language*. Cambridge, MA: MIT Press.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1987). Thinking and speech (N. Minick, Trans.). In R. W. Rieber & A. S. Carton (Eds.), *The collected works of L. S. Vygotsky: Vol. 1* (pp. 37-285). New York: Plenum Press.

Walker, J. (2005). *Design scenarios as a measure of adaptive understanding*. Paper presented at the American Educational Research Association Annual Meeting, Montreal, Canada.

Webb, N. M. (1989). Peer interaction and learning in small groups. *International Journal of Educational Research, 13*, 21-39.

Webb, N. M., Troper, J. D., & Fall, R. (1995). Constructive activity and learning in collaborative small groups. *Journal of Educational Psychology, 87*, 406-423.

Wenger, E. (1999). *Communities of practice: Learning, meaning and identity*. Cambridge: Cambridge University Press.

Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior & Development, 7*, 49-63.

Wertheimer M. (1959). *Productive thinking*. New York: Harper and Row.

Wertsch, J. V. (1998). *Mind as action*. New York: Oxford University Press.

White, B. C., & Frederiksen, J. (1998). Inquiry, modeling, and metacognition: Making science accessible to all students. *Cognition & Instruction, 16*(1), 39-66.

Whiten, A. (2002). The imitator's representation of the imitated: Ape and child. In A. N. Meltzoff & W. Prinz (Eds.), *The imitative mind: Development, evolution, and brain bases* (pp. 98-121). Cambridge: Cambridge University Press.

Wiggins, G. & McTighe, J. (1997). *Understanding by design*. Association for Supervision and Curriculum Development, VA.

Willis, P. (1981). *Learning to labor*. New York: Columbia University Press.

Wineburg, S. (1998). Reading Abraham Lincoln: An expert/expert study in the interpretation of historical texts. *Cognitive Science*.

Zech, L., Vye, N. J., Bransford, J. D., Goldman, S. R., Barron, B. J., Schwartz, D. L., et al. (1998). An introduction to geometry through anchored instruction. In R. Lehrer & D. Chazan (Eds.), *New directions for teaching and learning geometry* (pp. 439-463). Mahwah, NJ: Lawrence Erlbaum Associates.

Zhang, Y., Kuhl, P. K., Imada, T., Kotani, M., & Tohkura, Y. (2005). Effects of language experience: Neural commitment to language-specific auditory patterns. *NeuroImage 26*, 703-720.