Submitted Draft: April 4, 2005

Learning Theories and Education: Toward a Decade of Synergy

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To appear in: P. Alexander & P. Winne (Eds.), *Handbook of Educational Psychology* (2nd Edition). Mahwah, NJ: Erlbaum.

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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; 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; 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 lifespan 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 & Berliner (Chapter 1) provide an excellent introduction to the origins and goals of educational psychology. Mayer & Wittrock (Chapter 3) discuss research on transfer-–a key concept for educators. Greeno, Collins & Resnick (Chapter 2) examine important traditions of
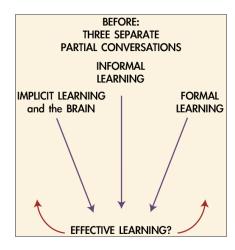
thought that have been used to analyze the processes of human learning--traditions such as the rationalist, empiricist, and socio-historical. Greeno et al. contrast the different ways in which these traditions have viewed cognition and learning, and how each tradition has contributed to the design of educational practices. For example, behaviorism—a 20th century expression of the 17th-18th century empiricist traditions of Locke and Berkeley—views learning as the strengthening of associations between stimuli and responses. In contrast, learning from the constructivist/rationalist tradition is conceptualized in terms of the growth of conceptual structures and general cognitive abilities such as reasoning and problem solving, Finally, the situative perspective, representative of the pragmatist-sociohistorical tradition, views learning as being intricately bound up with social interactions and cultural tools.
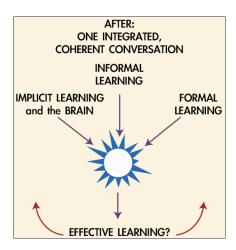
Greeno et al. also discuss major changes in how learning research has been conducted during the past 30 years--changes that involve moving from "laboratory only" studies to research conducted in complex environments such as classrooms, schools and districts (e.g., Brown, 1992; Collins, 1992; CTGV, 2000; 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 below.

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 science of learning, and transform 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 brain, (2) Informal learning, and (3) Designs for formal learning and beyond. As illustrated in Figure 1A, these three areas have tended to operate relatively independent 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.

Figures 1A and 1B

The goal of integrating insights from these strands in order to create a transformative theory of learning is illustrated in Figure 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 Figure 1. We then suggest ways that 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 twenty-first century (e.g., Darling-Hammond & Bransford, 2005; Vaill, 1996).

1.0 Implicit Learning and the Brain

The first strand illustrated in Figure 1 is implicit learning and brain. Its relevance to human learning is discussed below.

1.1 What Is Implicit Learning and Why Study It?

Implicit learning refers to information that is acquired effortlessly and sometimes without conscious recollection of the learned information or having acquired it (Reber, 1967; Graf & Schacter, 1985). There are many types of implicit learning, but a common process may underlie all forms — the rapid, effortless, and untutored detection of patterns of co-variation among events in the world (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 lifespan.

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), phonetic language learning (Goodsitt, Morgan, & Kuhl, 1993; Saffran, 2002; Kuhl, 2004), and young children's imitative learning of the tools/artifacts of their culture and the behaviors, customs, and rituals of their surrounding social group (Meltzoff, 1988b; 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 et al., 2004) or the ability of television news to teach citizens about how candidates stand on political issues (Krosnick & Branon, 1993; Schleuder et al., 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 et al., 2002; Trappey, 1996) or through frequent and implicit associations between people, places and appeals (Chang, 2002; Invernizzi et al., 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 their 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 et al., 1997). In some instances, it can be shown that "trying to learn" patterns of co-variation through explicit instruction actually impedes learning,

underscoring the idea that implicit and explicit forms of learning are different (Howard &

Howard, 2001). Recent 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

(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* (Howard &

Howard, 2001). (We explore the idea of what it means to "be in an environment" in more detail

in Section 4.0.)

The label "implicit learning" that we are using it 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 et al., 2003) and learning

about people, sometimes called "social cognition" (e.g., Ochsner & Lieberman, 2001; Flavell &

Miller, 1998; Meltzoff & Decety, 2003; 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.

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 apply across 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 are important for educators to know.

1.2 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 1990's were dubbed "The Decade of the Brain" and produced advances in neuroscience techniques. Modern neuroscience documents learning in an alive, awake brain, revealing the impact of experiential learning *before it can be observed in behavior*. This is a change from studies in the 70's and 80's 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.

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 (eg., Bruer, 1997, 1999; NRC, 2000; Gopnik, Meltzoff, & Kuhl, 1999b).

While 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, 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, bilingual exposure and its effect 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 Section 4.0.

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 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 behavior (Tremblay, 1999), 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 discussion below, we provide a few targeted examples that illustrate research on brain that raises important questions about understanding and optimizing learning.
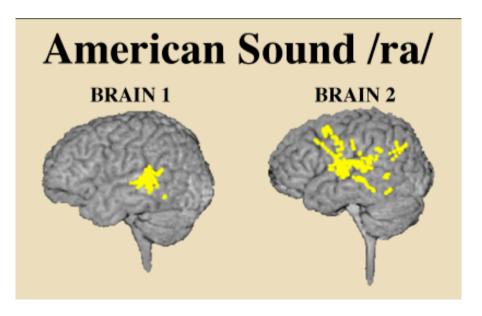
1.3 Learning to Interpret Brain Data

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, not an easy prescription. The methods require specialized equipment, have established literatures, and are rapidly changing. Our argument is that overcoming the complexity is worth the effort. Learning scientists can expect rewards, minimally for familiarization with the methods, and maximally from mastery that allows participation in a new cognitive neuroscience.

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. Equally important is the need to learn to interpret findings from brain research. An example is provided in Box 1.

Box 1.

The picture below depicts the spread of activation in the brains of two different people performing the same task. [Note that in this 2-D display. The activation is displayed on the surface of the brain; in reality, the activation is deep in the brain.] The spread of activation in the brain on the right is much greater than the one on the left. Is greater activation better or worse?

Many who look at the images in Box 1 believe that the greater activation shown in the brain on the right must indicate a better brain response. Actually, these two brain images are from a study of American (labeled "Brain 1") and Japanese adults (labeled "Brain 2") attempting to process the American English syllable /ra/ (Zhang et al., in press). This syllable is easy for Americans to recognize and code, but difficult for Japanese adults because the Japanese /r/ is different from the American /r/, and Japanese people do not distinguish /r/ from /l/. The brain image on the left shows an American listener processing /ra/ — the one on the right shows a Japanese listener attempting to process the same sound. The research technique used to generate these views of brains processing auditory information is magnetoencephalography(MEG). Analyses of the MEG data show that the Japanese brain is activated for a significantly *longer*

period of time and with greater *spread of activation* than the American brain. Speed and spatial activation are variables that brain scientists have used to examine efficiency in priming, practice, and learning tasks (see Poldrack, 2000 for review).

Researchers interpret these results as involving greater *neural efficiency* for a stimulus that is well known by the listener. More resources have to be activated in the Japanese brain for this task and the processing takes longer; it is less efficient. The greater efficiency of processing is illustrated by a more economic use of resources in the American brain. Importantly, when the same two groups of subjects listened to syllables contained in both languages (the syllables /ba/ and /wa/), or to non-speech analogs of the /ra/ and /la/ syllables, neural efficiency was identical in the two groups. The results show the advantage of prior learning on the brain's processing of information. Patterns learned early, learned quite literally for life, are processed automatically and with high efficiency. Strand 1 researchers presume that the neural efficiency embodied in the processing of these speech sounds then "frees up" the brain to devote processing to other matters. In this way neural efficiency for certain well-practiced signals can allow for increased attention and creativity in others.

There are many additional brain studies that also suggest greater neural efficiency (shown in the spread of activation and the duration of activation measures described in Box 1) when processing over-learned material (Callan, et al., 2004; Guenther et al., 2004; Dehaene et al., 1997; Golestani & Zatorre, 2004). However, we need to discover more about the brain when it initially learns something, especially during early childhood development when expertise develops. Presumably, as initial learning occurs--for example, learning of the sounds of language or words--the regions of activation would increase. Once the language system develops, the kind of efficiency that we see in adulthood might occur. Thus, one might predict a

U-shaped function in *neural efficiency* as learning occurs. In the initial stages of learning, as attention to important stimulus information increases, corresponding brain activation should also increase, and as expertise develops, activation should decrease (Kuhl, 2004). For more elaborate stimulation, for example when both auditory and visual speech events are presented (Kuhl & Meltzoff, 1982), greater activation would be expected.

It is 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 over half a century (see Kuhl, 2004 for review). Human cognition is complex, plus learning associated 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 forge. Nevertheless, there are important conjectures from brain research that are relevant to educators' thinking, and selected examples are provided below.

1.4 Some Key Brain Findings and their Importance

1.4.1 The Brain at Birth. It is a common misconception that each individual's brain is entirely formed at birth. Instead, experiences during development have powerful effects on the physical development of the brain itself. An example of a classic study on brain development is discussed in Box 2.

Box 2.
      A pioneering study on the effects of the environment on brain development was conducted by William Greenough and his colleagues (1987). They studied rats placed in various environments and the resulting effects on synapse formation in the rats' brains. They compared the brains of rats raised in "complex environments," containing toys and obstacles, with those housed individually or in small cages without toys. They found that rats raised in complex environments performed better on learning tasks, liked learning to run mazes, and had 20–25% more synapses per neuron in the visual cortex. This work suggests that brain development is "experience-expectant"—evolution has created a neural system that "expects" information from the environment at a particular time, allowing animals to acquire knowledge that is specific to their own environments when exposed to that information. These experiments suggest that "rich environments" include those that provide numerous opportunities for social interaction, direct physical contact with the environment, and a changing set of objects for play and exploration (Rosenzweig & Bennett, 1978, cited in NRC 2000, p. 119).

New advances in technology are allowing scientists to go beyond the study of animals and explore how humans process information. We know, for example, that if language experiences are not provided to humans in a social environment, language is not acquired. Tragic cases, like that of Genie, have been documented (Fromkin et al., 1974). Genie was a girl isolated from birth and found at the age of 13. She had been deprived of language and social interaction and never acquired the ability to speak.

One intriguing aspect of the human brain 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 (Werker and Tees, 1984; Kuhl, 2004). 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 (Zhang et al., in press; McClelland et al., 2001, 2002).

While synaptic development and subsequent "pruning" have received much attention in the press (perhaps because the reduction of synapses over time is counter-intuitive), it is a good 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.

1.4.2 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 (as elegantly described by Bruer, 1999). For example, people often question whether children who spend their early years in under-stimulating environments, will jeopardize 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 and learning is affected 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 differ 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; Rivera–Gaxiola, Silva-Peryra, & Kuhl, 2005). The idea behind the studies relies on the concept of *neural commitment* to learn language patterns. Kuhl's recent neuropsychological and brain imaging work suggests 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. The concept related to the "critical period" is Kuhl's claim that early learning both supports and constrains future learning. Early neural commitment to phonetic units supports the learning of more complex patterns, such as words that rely on phonetic learning. However, neural commitment to learned patterns also constrains future learning; neural networks dedicated to native-language patterns do not detect 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 promotes future learning and builds on the

patterns already experienced, limiting (or making more difficult) future learning of patterns that do not conform to the ones already learned. The "critical period" thus depends on experience as much as time, and is a *process* rather than a window. 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, Meltzoff & Kuhl, 1999a; Kuhl, 2004).

The general point is that learning produces 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(a)(b); Kuhl et al. 1992; Näätänen et al., 1997). This results in highly efficient processing of learned material (Zhang et al., in press). The most well studied example is language, but it is only one of many. In language, neural filters affect processing at all levels, from phoneme to grammar, making native-language processing highly efficient and foreign-language processing difficult in adults (Strange, 1995). Neural filters focus our attention and increase efficiency, which can be a great benefit, but also do so at a cost. Adults are no longer as open to new language learning as they were as young children.

Broadening this discussion, the neural commitment concept can be thought of as a neural instantiation of "expertise" in any domain. Expertise in many areas may reflect these kinds of filters on experience — filters that focus attention, and structure perception and thought, so that we work more efficiently and thereby freeing up our attention and energies to thinking creatively in other domains, but also limiting an 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 simultaneously remaining open for adaptive change. This is an issue that receives more attention in Section 3 when we discuss adaptive expertise.

1.4.3 Breaking Free from Existing Neural Commitments. In adulthood, second language learners have to overcome committed brains to develop new networks. As years of research attest, babies are better at learning language 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 et al., 1993). 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 live sessions, compared with a control group that heard only English, and that 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 any natural language that they hear (Kuhl et al., 2003).

However, infants' computation may be limited by their interest in the material. 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 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 experiments are needed before this strong claim can be accepted.

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 reduce complexity to manageable proportions. Clearly, however, 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 prototypical and well worked out example. For instance, experiments show that even with extensive training, adults often do not learn foreign-language contrasts (see Strange, 1995 for review). Recent experiments show that mimicking the features of infant-directed speech may help adult learners and even those with language impairments. In studies of Japanese adults, McClelland and his colleagues (McClelland et al., 2001; 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 train children with dyslexia to discriminate speech sounds. What is interesting about these cases is that adult-directed speech exaggerates and stretches the 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 et al., 2003). The argument advanced by Kuhl (2004) is 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, 2004 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 Section 3 (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 (see McClelland et al., 2001). Others have shown that learners do best with more complexity, and that optimal learning is produced when many talkers' sounds are presented during training (see Pisoni et al., 1993). The newer research again takes a lesson from infant learning; adults addressing infants and children adjust speech in ways that appear to be helpful to language learning (Kuhl et al., 1997; Liu et al., 2003; Burnham et al., 2002).

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

Other studies by brain and developmental scientists are relevant to a science 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 lifespan (e.g., 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, et al., 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 also 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.
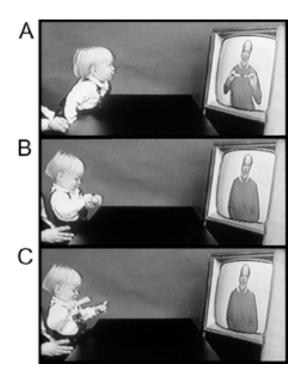
One possibility is that even a simple act of imitation is connected with perspective-taking and therefore is more of a social, collaborative activity than it first appears (Meltzoff, 2005). Consider that the model or teacher and child rarely see the world from the same perspective. The child sees her own body and own actions from a "first person" perspective; but we see others from a "third-person" perspective. Imitation requires that the child watches the adult and is able to "transform" it 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 under-girds 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 affective perspective taking that requires us to stand in another's shoes (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 the their peers in day-care centers (Hanna & Meltzoff, 1993). Another showed that preschoolers learn novel actions from TV (Meltzoff, 1988a). This is an important finding because young children in Western culture watch a good deal of TV. According to both Nielson (1987) and Kaiser Foundation (Rideout, Vanderwater, & Wartella, 2003), the average 2- to 5-year-old views about 28 hours per week of TV. Television pictures present a miniaturized, two-dimensional depiction of three-dimensional space. To prove that infants can learn from television it is not enough to know that young children are visually captured. They may simply be attracted to the visually changing mosaic of colors. But the Meltzoff (1988a) study went beyond assessing "visual interest." 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 (see Figure 2).

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 television. 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 months 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 for infants and

preschoolers.

Figure 2. Children under 2 years of age will imitate novel actions they see on TV, such as pulling apart this dumbbell-shaped object. Few children in control groups do this act spontaneously, but a significant number of children do so after watching the adult show the action on TV. Research is continuing on what factors make effective media learning environments for children. (From Meltzoff, 1988a)

2.0 Informal Learning

The second strand of research illustrated in Figure 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, non-school public settings like 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% of a child's waking activities, during their school age years, are spent in non-school pursuits—interacting with family and friends, playing games, consuming commercial media, and so on (NRC, 2000). If we extend this calculation to the human lifespan, the percentage of time spent outside of school, and therefore a potential source of informal learning, would be over 90%. 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 non-school life both in occupational and every day contexts.

Informal learning is understudied, which is surprising given the emphasis that developmentalists, educational psychologists, and cognitive scientists have placed on the importance of understanding learners' prior knowledge. Although informal learning is understudied when compared with learning in schools, 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 that need to overcome to develop normative knowledge. 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, 2003(a)(b)). 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.

The origins of the informal learning tradition are diverse and are most readily understood as an affiliated set of approaches and ideas that can be contrasted with mainstream psychology and educational psychology. For example, informal learning research typically takes an ecological conceptual stance and an ethnographic methodological approach, seeking to study how people learn in "their" informal settings with sustained attention paid to "indigenous meanings and local phenomena" (Emerson, 2001, p. 136). Research on learning and cognition outside of laboratory settings often has been critiqued by mainstream educational psychology as lacking experimental control and internal validity (whereby inferences made from the operationalizations in a study are legitimately drawn to the theoretical constructs upon which the operationalizations are based, e.g., Cronbach & Meehl, 1955). Informal learning research has typically placed its emphasis on *ecological validity* and has made the counterargument; laboratory research is very often lacking in this type of external validity. Some have gone so far as to argue that ecological invalidity is axiomatic of laboratory research (Cole, Hood, & McDermott, 1978).

Despite these differences between informal learning and other perspectives that we elaborate in this section, we feel that the learning tradition described in this section is essential to "the decade of synthesis" that the LIFE project seeks to promote (see Figure 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. 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 Section 4.0. Articulating these principles also creates opportunities to forge new trans-disciplinary connections, both in terms of new approaches to research on learning and to new educational projects informed by such a synthesis.[1]

2.1 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 twentieth 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, Goldman and Varenne (2003), an informal learning perspective is clearly present in Margaret Mead's *Coming of Age in Samoa*

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[1] An 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 claim that studies of situated action can be easily subsumed by a cognitivist symbol system approach (1993).

(1928) and is developed further in Mead's continuing work with Gregory Bateson. As

McDermott 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
> (McDermott, 2001, 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). The significance of the paper

for the informal learning tradition has little to do with the illicit "skill" it addressed, but rather

with the novel way it conceptualized learning. In this paper 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. (Becker, 1953; 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 bio-physical 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 earliest studies to locate the

development of identity as a dimension of learning (e.g., Becker & Carper, 1956). As we will

describe below, 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 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, like 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 non-schooled 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

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[2] Bruner 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).

[3] For a partial history of the LCHD (1972-1984) from Cole's perspective, see http://lchc.ucsd.edu/Histarch/lchc.history.html.

what Labov called a deprivation view and what has come to known as the "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 while 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 performance 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 "non-verbal" 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.

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

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. Such a commitment has always placed it at the margins of mainstream psychology, rooted in the founding late 19th century laboratory tradition of Wundt. For those psychologists working in the comparative tradition (e.g., Cole, Scribner, and their colleagues), their new goals and their prior disciplinary moorings in psychology led them to seek to satisfy competing methodological traditions by combining fieldwork with more controlled experimentation. This combination of research practices, while desirable for purposes of triangulation (Cronbach, 1975), remain in an unresolved tension because of potentially incommensurable standards of validity for research (Cole, Hood, & McDermott, 1997).

A well-elaborated program of research that combined fieldwork and experimentation was led by Sylvia Scribner. This approach is exemplified in Scribner's studies of learning and cognition among dairy workers (Scribner & Fahrmeir, 1982; Scribner, 1997a, 1997b). 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 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 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, Nunes, & Schliemann (1985). Regardless of disciplinary background, studies by all of these scholars shared one important common feature—they employed fieldwork methods, often along with posed tasks, to explore the

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

relations between informal learning and learning in schools. An important early volume that recognized the shared interdisciplinary space developing around informal learning was *Everyday Cognition* (Rogoff & Lave, 1984). A decade later, a similar volume entitled *Ethnography & Human Development* (Jessor, Colby, & Schweder, 1996) showed how far this interdisciplinary conversation had proceeded.

A history of informal learning research can also be told through the places where it has been at least partially institutionalized as a going research concern and in this regard, two "centers" warrant special mention. The first is the Laboratory of Comparative Human Cognition (LCHC), led by Michael Cole from its inception in 1972. The second was the Institute for Research on Learning (1986-1999), a private research institute whose interdisciplinary research staff included anthropologists, sociolinguists, educators, and cognitive and computer scientists. IRL is perhaps best known as the home of the influential volume *Situated Learning* (Lave & Wenger, 1991), but it, like the LCHC, has a rich and varied history of research and practical educational work related to informal learning.[6] Three more recent organizational settings are worth mentioning as ones where the details of informal learning are being further studied. These are the Center for Informal Learning and Schools (CILS), and the Learning in Informal and Formal Environments (LIFE), both funded by the National Science Foundation,[7] and the Center on Everyday Lives of Families (CELF), funded by the Sloan Foundation.

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

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(NRC – scientific research in education report).

[6] It is beyond our scope and abilities to tell adequate history of either of these complex institutions. For a partial history of the LCHC (1972-1984), see Cole (1984). The history of IRL remains to be told.

[7] CILS has a greater focus on what we earlier called informal education (e.g., museums) and LIFE has a greater focus on informal learning (e.g., in homes, at work, at play), but there are areas of overlap between them.

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, as we describe in the next section.

2. 2 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.

2.2.1 Clarification of the Role and Meaning of C*ontext* 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 Philip's (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 & Stevens (1995), 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, the challenge is to the view of 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 asituational" (Suchman, 1995, p. 72; for related views, see Eckert, 1989; Willis, 1981).

2.2.2 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 non-school 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.

        2.2.3 New Theoretical Constructs for *What Changes When* People Learn. In the machine cognitive era, psychologists have typically view 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). 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.[8]

2.3 Promising Directions for Informal Learning Research

Among the three broad traditions of studying learning described in this chapter, informal learning is the most attuned to the situated and context-bound aspects of learning. As already described, theoretical accounts are often tied to the local ecological conditions of action, interaction, and infrastructure; the affordances of specific tools; and the desires and purposes of specific individuals or groups. This leads to accounts with a focus on specific detail and context-boundedness that is at odds with the nomothetic accounts of learning sought by traditional psychological and sociological paradigms of research (cf. Erickson, 1986). Despite these differences, it is also possible that juxtaposing accounts from these traditions can generate productive ideas for research and theory (Becker, 1996).

As documented in the previous sections, research on informal learning and everyday cognition has progressed in fits and starts. Yet, just as the last two decades of research on learning in school environments have reshaped our understanding of human cognition and influenced educational practice (NRC, 2000), 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.

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[8] By 'complex system' Hutchins is referring to the different levels of "representational structure" that exist within and across people and tools. His view is perhaps the most promising starting place for building a synthetic view that brings together what changes within and around a person when learning happens.

2.3.1 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 "low brow" work (Scribner, 1997b; Beach, 1993; Rose, 2004) to "highbrow"

professional work (Hall & Stevens, 1995; Hall, Stevens, and Torralba, 2002; Hutchins, 1995;

Jacoby & Gonzalez, 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 like "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 et al., 2003; Schegloff 1992). In addition, 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 hetero geneous 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 non-school 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 socio-economic status, an issue of importance for translating findings from basic research to the educational goal of developing more equitable learning environments.

2.3.2 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 day[9]) and diachronic (i.e. as people move from post-secondary "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)[10] 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 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

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[9] A 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).

[10] See McDermott, Goldman & Varenne (1984).

initiatives organized around the concept of young people's "funds of knowledge" (Gonzâlez, Moll & Amanti, 2005; see also Heath, 1983; Lee, 1995).

3.0 Designs for Formal Learning and Beyond

The third strand of research illustrated in Figure 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 (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). These include:

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?

3.1 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. National standards are typically tailored to state standards that in turn are tailored to more local standards. These standards can have important effects on the design of curriculum, instruction and assessment in schools.

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., NCTM, 1989, 1995, 2000; NRC, 1996; Project Achieve at www.achieve.org).

Efforts to define standards represent an important advance in US 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.

3.2 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 & Osura, 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.

3.2.1 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). For example, Berliner (1991, 2001) demonstrates large differences in noticing by novice versus expert teachers; these differences in pattern recognition affect their abilities to rapidly identify problems and opportunities and do something about them. Classic work with chess masters was among the first to demonstrate the role of noticing and pattern recognition in expertise (e.g., Chase & Simon, 1973; deGroot, 1965; Chi et al., 1988; NRC, 2000).

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, an emphasis on expertise and noticing suggests that we do not simply learn *from* experience; instead, we also learn *to* experience (this was also pointed out in Section 2 in the discussion of Becker's 1953 example of becoming a skilled marihuana user; also see Stevens & Hall, 1998, and Pea's 1987 arguments on the social nature of the knowledge transfer problem in terms of learning to notice transfer relevancies by means of categories that are socio-cultural constructions). 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.

3.2.2 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).

As we note in more detail later, 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) makes the following argument about knowledge organization:

> "The curriculum of a subject should be determined by the most fundamental
> understanding that can be achieved of the underlying principles that give structure
> to a subject. Teaching specific topics or skills without making clear their context
> in the broader fundamental structure of a field of knowledge is
> uneconomical…An understanding of fundamental principles and ideas appears to
> be the main road to adequate transfer of training. To understand something as a
> specific instance of a more general case – which is what understanding a more
> fundamental structure means – is to have learned not only a specific thing but also
> a model for understanding other things like it that one may encounter." (pp. 6, 25
> & 31)

In agreement with Bruner, 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).

3.2.3 Expertise and Teaching. Information about relationships 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. They may therefore be much more inclined to follow only the restricted set of activities in the textbook where answers are provided in the teachers' manual.

There is also a downside to having a great deal of knowledge about one's subject matter. The information becomes so intuitive that experts lose sight of what it was like to be a novice. In his studies with chess masters, deGroot (1965) notes how masters were often incredulous that lesser experienced players could not see "obvious" features of the game board that were "right before their eyes" and signaled clearly what the next move should be.

Nathan, Koedinger and Alibali (2001) use the term "expert blind spots" to refer to one of the downsides of content expertise. 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. For example, experts in physics and engineering may not realize that they are failing to communicate all the information necessary to help novices learn to construct their own free

body diagrams (Brophy, 2001). The reason is that many decisions are so intuitive that the professors don't even realize that they are part of their repertoire.

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. A publication from the National Academy of Education (Darling-Hammond & Bransford, 2005) includes an informative chapter by Grossman, Schoenfeld and Lee (2005) on pedagogical content knowledge.

3.3 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 experts develop a core set of competencies that they apply throughout their lives with greater and greater efficiency. In contrast, adaptive experts are much more likely to change their core competencies and continually expand the breadth and depth of their expertise. This often requires them 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).

This restructuring of core ideas, beliefs and competencies can be a highly emotional experience (e.g., Gopnik & 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 wrong, 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*[11] 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.

3.3.1 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, in press). These two dimensions are illustrated in Figure 3.
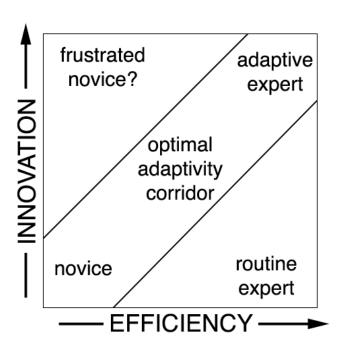

Figure 3. Two Dimension of Adaptive Expertise

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[11] http://www.businessweek.com/chapter/christensen.htm

The horizontal dimension in Figure 3 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 example, are presumably high on both dimensions (e.g., Gentner, Brem, Ferguson, Markman, Levidow, Wolff & Forbus, 1997; Hatano, & Inagaki, 1986; Wineburg, 1998).

It is noteworthy that different theorists and theoretical traditions can be represented by particular dimensions of Figure 3. 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 3 reminds us that different dimensions of learning exist.

Some educators, in contrasting theorists such as Dewey versus Thorndike, have asked "who is right?" The representation of adaptive expertise in Figure 3 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. The issue may well be how to strike a balance in developing expertise that plays to the strengths of both efficiency and of innovation. How this may be achieved is a frontier issue for research in learning sciences and education.

3.4 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 twenty first century.

3.5 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 twenty first century**.** In particular, if we return to the adaptive expertise dimensions shown in

Figure 3, 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, in press). 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 drivers 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, in press) 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 insure 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).

3.5.1 Beyond Efficiency Measures. Research conducted during the past five 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 & Bransford (1998), Bransford & Schwartz (1999), Schwartz and Martin (2003), Martin and Schwartz (in press), and Spiro, Vispoel, Schmitz. Samarapungavan & Boeger (1987).

It is important to emphasize that the PFL perspective is different from the older (but still important) learning-to-learn literature. A major reason is that PFL does focus primarily on the

existence of a set of general learning skills 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" vs. 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 causes 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 also 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 (Schwartz, Blair, Davis, Chang & Hartman, 2005; Martin, 2005; Petrosino, 2005; Walker, 2005; Hodge & Brophy, 2005; Crawford, Riel & Schlager, 2005; Hatano, 2005)

3.6 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; Schank & Abelson, 1977; Black and Bower, 1980; Bransford & Johnson, 1972). These are very important for allowing people to solve problems more efficiently. A great deal of the instruction in schools attempts to help students learn to 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 & Holyoak, (1980, 1983) and others (e.g., Adams, Kasserman, Yearwood, Perfetto, Branford & Franks, 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, etc.). The acquisition of well-organized and fluently accessed procedures, script and schemas is extremely important for effective performance--otherwise people are overwhelmed by attentional demands (e.g., see Bereiter & Scardemalia, 1993; NRC, 2000, Chapters 2 & 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).

3.6.1 Beyond Schema-Based Applications. We argued earlier than 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 non-routine 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: NRC, 2005; Gopnik, et al., 1999). 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 earth". For most people this will not be life threatening nor 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 metcognitively-rich activities that engage them in (a) "knowledge building" rather than merely "knowledge telling" (Scardamalia & Bereiter, 1989, 1993), 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 maybe first be asked to grapple with

issues and try to solve them, which them 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 over-assimilation (e.g., Schwartz & Bransford, 1998; Schwartz & Martin, 2004; Schwartz, Bransford & Sears, in press). 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.

3.6.2 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, Schwartz, Bransford, Barron, Zech & CTGV, 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 of efficiently and 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, Zech, Schwartz, Barron, Vye & CTGV, 2000) by leveraging "distributed intelligence" (Pea, 1993). Working smart assessments combine the dimensions of innovation and efficiency shown in Figure 3.

The idea of helping students learn to create tools for working smart can be illustrated in the context of an implementation study in which schools from nine different states were using the *Jasper Problem Solving Series* (e.g., CTGV, 1997). *Jasper* adventures are video-based narratives that create a story context for anchoring sustained mathematical problem solving. The researchers created a *Challenge Series* where classes and schools from different states would try to solve problems posed over satellite television (this was before the internet was ubiquitous).

The problems were "what if" analogs that varied specific quantities and constraints of the original *Jasper* problems they had solved. The *Jasper* challenges were exciting for students, teachers, parents and community members, but the design of the instruction had a conflict inherent, because it included a mismatch between goals of efficiency and innovation. The overall goal of the Jasper series was to encourage deep and innovative thinking. However, the challenges the students received were time limited and required fast, efficient thinking. This mismatch is common to many creative curricula (e.g., thinking skills programs) where students complete innovation activities but frequently get assessed in terms of efficiency –oriented standardized tests.

The "working smart" assessments changed the task context surrounding the *Jasper* adventures from "one shot problem solving" to "learning to deal with quasi repetitive activity cycles" (QRACS). For example, in one adventure called, *Rescue at Boone's Meadow* (CTGV, 1997), students initially were asked to engage in "one shot" problem solving by helping Emily rescue a wounded eagle by considering a number of variables such flying time, payload limitations, speed and gas consumption for an ultra-light plane, and so forth. In the QRAC version of this adventure, Students had to learn to "work smart." Their task was to help Emily run a rescue and delivery service that involved three ultra-light planes that could carry different payloads, flew at different speeds, and had different degrees of fuel consumption. The students had to help clients of Emily's company figure out travel times to and from specific regions, costs, and so on. In the context of their imaginary job, students confronted sets of "quasi repetitive activity structures" (QRACS) such as answering sets of distance/rate/time and fuel consumption problems that recurred frequently as customers asked for relevant information. Solving each problem anew (even with a calculator) is inefficient and error-prone. Ultimately,

students learned to develop tools such as graphs and spread sheets that allowed them to work smart and perform much better at answering "clients' questions" than groups who stuck only with their calculators. And students learned that failure is not an option—they need work at very high levels of accuracy. Examples are discussed in more detail elsewhere (e.g., Bransford et al., 2000; Vye et al., 1998; Zech et al., 1998).

4.0 Looking Toward the Future

In this section we ask how work in the three research strands discussed above (see Figure 1) can 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 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. There are number of ways that this synergy can be accelerated. All require focused interaction to help people from different strands (research traditions) learn to talk to one another in ways that affect their subsequent research trajectories. Examples of ways to accelerate collaboration are provided below.

4.1 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 three examples -- many more are possible as well.

4.1.1 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 9 month-old American children 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 "super normal" stimuli with beautiful records of the facial expressions and lip moments 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 learning 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.

4.1.2 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.

4. 2 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 are therefore powerful sources of learning. 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 tool in their culture (e.g., Gopnik et al., 1999; Meltzoff, 2005).

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 (Johnson & Johnson, 1981; Stevens & Slavin, 1995; Barron, 2000). 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 & Iganaki, 1991; Webb, 1989).

Detailed video analyses 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 -- and 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), Huang-Yao Hong (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); Huang-Yao Hong, 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 Figure 1.

4.3 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 7 "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 in so doing promote a widespread research initiative for the field that is high quality and 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., Penuel & Yarnall, 2005; Minstrell, 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" website (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 & Hall, 1997; Stevens, Cherry & Fournier, 2001; 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.

4.4 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, 1987) can help surface (often tacit) assumptions that can then be compared. There are at least two approaches one might take towards conceptual collisions. One anchors the collision around important principles that guide thinking about learning. The other anchors the collision around common phenomena.

4.5 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.

4.5.1 Preconceptions. The books *How People Learn* (NRC, 2000), *Learning and Instruction: A SERP Research Agenda (NRC, 2003), How Students Learn* (NRC, 2005), and *Preparing Teachers for a Changing* World (Darling-Hammond & Bransford, 2005) summarize a number of studies that demonstrate the active, preconception-driven learning that is evident in humans from infancy through adulthood. For example, college physics students who do well on

classroom exams that test concepts like the laws of motion often revert to their untrained, erroneous models outside the classroom unless they are helped to change fundamental preconceptions that they bring to their studies (e.g. diSessa, 1982).

The three traditions of research add complimentary perspectives to understanding the role of preconceptions. Strand 3 points to the efficiency x innovation characterization of adaptive expertise illustrated in Figure 3. 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 & Scardemalia, 1993). Often, however, efficient access to knowledge and skills results in the over-assimilation 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 automatized (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 over-assimilate. This would correspond to the Strand 1 argument that implicit learning leads to neural commitment, so that some ways of thinking become highly efficient, but at the expense of learning new ways of thinking.

As discussed in Section 1, Strand 1 researchers emphasize both the advantages and the disadvantages of neural commitment in areas of expertise, such as native language. Disadvantages are illustrated in second language learning, which is made 'more difficult' if learned late in life when the brain is already neurally 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 over-coming neural commitment will require exposure to new patterns of co-variance that fall outside the normal pattern, experience in a sense, that does not support the initial "mental filter" or preconception. The exposure to new instances will 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. For example, they might argue that it is important to develop social patterns of participation and mediation that help people transition back and forth between everyday preconceptions and the more formal treatments characteristic of school. Strand 3 would further broaden the debate by raising the idea that students need explicit opportunities to innovate by "letting go while leveraging" their preconceptions, and that an explicit understanding of assimilation versus "letting go" can prepare them for future learning.

Overall, the three strands provide different perspective on a fundamental principle, and each strand can help nuance one another's claims. For example, a complete, educationally relevant account of implicit learning will need to include an explanation of , whether, when and how explicit efforts to shape one's context and activity can change what is available to the implicit learning mechanisms, and what teaching processes may be best to maximize the benefits and minimize the disadvantages of highly efficient neural commitments in areas of great expertise.

4.5.2 Learning with Understanding. A number of studies show that novices often focus on surface features of concepts (e.g., Chi, Feltovich and 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 ignificance 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" is a convenient expression that actually means that people have seen enough instances that they can infer (albeit sometimes through an 'unconscious inference') the casual 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 supports 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.

4.5.3 Metacognition. The third learning principle noted above 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., White & Frederiksen, 1998; Lin & Lehman, 1999; Dufresne, Gerace, Leonard, Mestre, & Wenk, 1996; NRC, 2000; Vye et al., 1998), mathematics (Shoenfeld, 1992) and reading comprehension (e.g., Palincsar & Brown, 1989; Brown & Campione, 1994, 1996; Pressley, 1995).

Donovan and Bransford (2005) also note 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 mindset 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. 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 approach to exploring conceptual collisions is to collect multiple perspectives on relatively concrete anchoring phenomenon. An example is provided below.

4.6 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 upon. To illustrate, consider a vignette of a novice going in a boat with an expert fisherman who takes the novice to a good spot on the lake, then helps him select the right bait and set the hook at the right depth, shows him how to set the hook, and so forth. The novice catches several fish and feels good about his efforts. A month later the novice comes back to the lake by himself. He returns to the spot and repeats the previous behaviors because he was successful earlier. The challenge asks if this is a good example of implicit learning, of informal learning, of formal learning, and why or why not. Several "collisions of ideas" emerged from this simple exercise that were surprising to the LIFE members and raised important questions about learning like those noted below.

4.6.1 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 one month later and

slavishly repeating the previous behaviors without variation and adaptation to the current

situation may be undesirable. As noted in Section 3, people learn *to* experience as well as *from* it

(e.g., see discussions of noticing in NRC, 2000; Pea, in press, on "guided noticing" using new

video tools; Stevens & Hall, 1998, on "disciplined perception") As researchers, we all need to

clarify what "learning from experience" (be it implicit, informal or formal learning) might mean.

4.6.2 Issue 2: Multiple levels of simultaneous learning?. Comments on the challenge

from Strand I researchers 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 Box 3.

Box 3.

(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 over-fish. 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.

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(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 "enjoy nature and 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 their lifetime. 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 in Section 2, 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".

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.), I am (or am not) liked by my peers or my teacher", etc. 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 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 (Section 1.0) provides important clues about exploring this question in more detail.

It is important to explore the issue of "multiple levels of learning" because it 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.

4.6.3 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 non-school 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.)?

Ultimately, people with certain sets of skills need to be "cross trained" to learn others' skills. But an important feature of everyday environments may be that they are often motivating 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. Some curricula provide

opportunities for many different kinds of contributions to group problem solving and this has had

important effects on their motivation, group acceptance, and ultimate eagerness to learn (e.g.,

CTGV, 1997). But there is a great deal of room for innovation in this regard.

       4.6.4 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 section 3.0 we discussed "working smart"

curricula that utilize some of the QRAC structures that seem characteristic of many activities in

the workplace and everyday life.

4.6.5 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%) 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.

5.0 Chapter 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 Sections 1, 2, and 3 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 search for "conceptual collisions" that can hopefully 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. Hopefully, however, 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 formable but exciting challenges of helping all learners succeed.

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