The Rebirth of Children's Learning

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Learning is a central part of children's lives, but the study of learning is a rather peripheral part of the field of cognitive development. Fortunately, this situation is starting to change; recent theoretical and methodological advances have sparked renewed interest in children's learning. This renewed interest has already yielded a set of consistent and interesting findings regarding how children learn, as well as intriguing proposals regarding the mechanisms that underlie the learning. Increasing our focus on children's learning promises to yield practical benefits as well as a more exciting field of cognitive development.

INTRODUCTION

At one time, children's learning was the central topic in developmental psychology. This has not been the case for many years, however. With the cognitive revolution in adult experimental psychology and the rise of Piaget's theory within developmental psychology, the emphasis shifted from learning to thinking. This shift laid the foundation for a rich and vibrant field of cognitive development. The gains, however, came at a cost. We now know quite a bit about children's thinking at different ages, but we know little about how they get from here to there. In a sense, we threw out the baby of learning with the bath water of associationism.

The movement away from studying children's learning reflected more than a shift in interest; it also reflected an assumption that development and learning are fundamentally different processes. Piaget frequently distinguished between development, by which he meant the active construction of knowledge, and learning, by which he meant the passive formation of associations. Active developmental processes were of interest; passive learning processes were not. This distinction was valuable in focusing attention on children's efforts to make sense of the world and in exposing hidden assumptions that had shaped previous research on children's learning. However, Piaget's stance had the unfortunate side effect of producing skepticism about the importance of any kind of learning for development. This led to a drastic decline in studies of children's learning. As Stevenson (1983) commented:

By the mid-1970s, articles on children's learning dwindled to a fraction of the number that had been published in the previous decade, and by 1980, it was necessary to search with diligence to uncover any articles at all. ... The discussion of children's learning had been displaced by a newfound interest in cognitive development (p. 213).

Prominent successors to Piaget's theory, in particular neo-instructivist and theory-theory approaches, also have focused on children's thinking, largely to the exclusion of their learning. The research that they have inspired has expanded our understanding of development by revealing substantial, domain-specific, cognitive capabilities that children possess from early in life and by demonstrating the key roles of causal connections, often mediated by unobservable constructs, in these early understandings. Like Piaget's theory, however, they have told us little about how children come to have these understandings.

It is no accident that recent theories have focused more on the ways children typically think at particular ages than on the processes by which they learn to think in more advanced ways. Intellectually, it makes sense to map out landmarks within the developmental progression before trying to specify the mechanisms by which children move from here to there. Logistic factors militate in the same direction; simply put, it is easier to determine what children know at different ages than to determine how they acquire the knowledge. Research approaches also create their own momentum; the great recent progress in understanding certain topics that have been in vogue, such as understanding of other people's minds and of living and nonliving things, has raised numerous interesting questions regarding alternative interpretations and potential extensions of previous findings.

Arrayed against these varied factors that exert pressure toward continuing to focus on how children think, rather than on how they learn, is one central fact: learning is a central part of children's lives. Learning probably is even more central in the lives of children than in the lives of adults. Adults frequently have considerable expertise with the tasks they undertake. As they gain experience, they continue to learn, but
much of the learning involves relatively small refinements of existing competencies rather than acquisition of new capabilities. In addition, how well they perform in their jobs and in their other everyday tasks such as driving is important to their own and other people’s well-being. Thus, performance is very important in adults’ lives, relative to learning.

In contrast, childhood is a period of life in which learning plays a particularly large role relative to performance. Infants, toddlers, and preschoolers frequently need to acquire new capabilities; their ability to learn is very important. On the other hand, how well they perform any given task at a given time ordinarly is unimportant. The quality of the pictures they draw, their skill at playing games, and their knowledge of songs and television characters matters little. What is important is that they, and school-age children, learn to act in ways that will allow them to perform effectively in future settings. Five hundred years ago, 14-year-olds were adults, because they had learned enough that they could function as adults; today, they are children, because they need to learn so much more before they can function in adult capacities. Thus, although learning is important for adults, it plays an even larger role in the lives of children. Any theory of development that has little to say about how children learn is a seriously limited theory of development.

The importance of children’s learning for a coherent understanding of development has led a small but increasing number of investigators to take on the challenges associated with studying it directly. These investigators come to the task from a variety of theoretical backgrounds: neo-Piagetian (e.g., Fischer & Bidell, 1998; Karmiloff-Smith, 1992), cultural contextualist (Ellis & Gauvain, 1992; Granott, 1993), dynamic systems (Thelen & Ulrich, 1991; van Geert, 1998), and information processing (Johnson & Morton, 1991; Munakata, 1998; Siegler, 1996). They do not study learning of paired associates or nonsense syllables. Instead, they investigate how children learn meaningful concepts and skills such as object permanence, reaching, face recognition, scientific and mathematical problem solving, arithmetic, and so on. Thus, the new field of children’s learning, unlike the old one, emphasizes acquisition of concepts and skills that are important in children’s lives.

Despite differences in the investigators’ theoretical orientations, modern investigations of children’s learning have yielded highly similar results. Such commonalities are especially encouraging, because they suggest that the regularities in children’s learning are sufficiently strong that they shine through differences in investigators’ preconceptions and specifics of tasks, content domains, and populations.

The empirical studies that have revealed the commonalities in children’s learning rest on a foundation of recent theoretical and methodological advances. The next two sections of this article examine these theoretical and methodological advances; the following section highlights four findings that have emerged consistently from the empirical research; and the final section focuses on two key issues for future consideration: the relation between learning and development and educational implications of current research on children’s learning.

**EMERGING THEORIES OF CHILDREN’S LEARNING**

In the past few years, theoretical proposals regarding children’s learning have increased considerably in both number and precision. A wide range of theoretical approaches have contributed to this trend, as is apparent in the chapters of the most recent Handbook of Child Psychology (Damon, 1998). In a chapter focused on information processing approaches, Klahr and MacWhinney (1998) noted that beneath the superficial differences between connectionist and symbolic information processing models of children’s learning, there are important similarities. Both types of models indicate that learning involves considerable parallel processing; that it influences the activations of many local units rather than being limited to high-level changes such as those envisioned in stage approaches; and that it produces qualitative as well as quantitative change.

Rogoff (1998) emphasized that within sociocultural approaches to development, learning involves not just increasing knowledge of content but also incorporation of values and cultural assumptions that underlie views about how material should be taught and how the task of learning should be approached. Case’s (1998) examination of neo-Piagetian theories provides a third example. He proposed that children learn new information by organizing it to fit central conceptual structures for thinking about number, space, and other domains. To cite a fourth example, Gelman and Williams (1998) examined constraints on learning. They argued that all theories of cognitive development posit that learning is constrained, that almost all of the theories recognize that many of the posited constraints help rather than hinder learning, and that the theories vary more in their views regarding the specificity and origins of the constraints than in whether learning is constrained. Finally, Spelke and Newport (1998) proposed that innate knowledge provides the building blocks from which more refined and culturally contingent learning is later created. Thus, although neither neo-Piagetian nor information pro-
cessing nor sociocultural nor neonativist theories have focused primarily on how children learn, all are devoting increasing attention to it.

One theory that does focus primarily on children’s learning is the overlapping waves theory (Siegler, 1996). This theory is based on three assumptions: (1) children typically use a variety of strategies and ways of thinking, rather than just a single one, to solve a given problem; (2) the diverse strategies and ways of thinking coexist over prolonged periods of time, not just during brief transition periods; (3) experience brings changes in relative reliance on existing strategies and ways of thinking, as well as introduction of more advanced approaches.

A schematic illustration of these assumptions is provided in Figure 1. Examination of any vertical slice of the figure indicates that multiple approaches are used at one time. Comparing several vertical slices indicates that relative frequencies of strategies shift continuously over time, with new strategies sometimes being added and older strategies sometimes ceasing to be used. Following the curve for a given strategy indicates that a single strategy will often be used for a protracted period, even after later-developing, more advanced approaches are also known.

The cognitive diversity postulated by overlapping waves theory appears to be present at every level of analysis. It is present within individuals as well as across them; in studies of arithmetic, serial recall, spelling, time telling, and other tasks, most children used at least three strategies (Siegler, 1996). The variability also is evident within an individual solving the same problem on two occasions close in time; presented the same simple addition problem or the same time on an analog clock, one third of children used different strategies on two presentations within a one-week period (Siegler & McGilly, 1989; Siegler & Shrager, 1984). The variability is even present within a single trial. Children sometimes express one strategy in speech and a different one in gesture on the same trial (Goldin-Meadow, Alibali, & Church, 1993). Other times, verbalizations alone reveal multiple strategies; for example, children frequently use category naming and rehearsal on a single free recall trial (Coyle & Bjorklund, 1997). This last phenomenon—cognitive variability within a single trial—raises interesting challenges for formal models of strategy choice. To date, such models have focused on situations in which a single strategy is chosen on a given trial (e.g., Siegler & Shipley, 1995). However, the models could be extended in any of three ways to choosing among multiple strategies on a single trial. One possibility is that two or more strategies could be organized into a linked unit, and the linked unit could be chosen; thus, children might on one trial choose “name a category and rehearse its members,” though on another trial they might choose one of the component strategies (e.g., “name the category”) alone. A second possibility is that separate strategy choices could be made at different times within a trial; children might first choose category naming as a strategy and later in the trial choose rehearsing the members of the category. A third possibility, especially applicable to cases where different strategies are expressed in different modalities, is that strategy choices could be made in parallel in the two modalities; thus, children might choose one strategy in gesture and simultaneously choose a different one in speech. These possibilities are not exclusive; all are plausible, and all may be used.

Overlapping waves theory also specifies four dimensions along which learning occurs: acquisition of novel ways of thinking, more frequent use of the more effective ways of thinking from among the existing possibilities, increasingly adaptive choices among alternative ways of thinking, and increasingly efficient execution of the alternative approaches.

The most obvious dimension of learning is acquisition of new, more advanced ways of thinking. Such acquisition can occur through drawing analogies to better understood problems, through direct verbal instruction, through forming mental models of the situation and reasoning about them, or through observations during the course of problem solving (Anderson, 1991; Sternberg, 1985). Acquisition of new strategies involves a mix of associative and metacognitive processes, and also a mix of conscious and unconscious processes. In at least some cases, new strategies are constructed on an unconscious level before people are aware of doing anything different than they had done previously; behavioral indices show that new approaches are being used, although verbal

![Figure 1 Schematic depiction of the overlapping waves model.](image-url)
reports of use of the new strategy lag slightly behind (Siegler & Stern, 1998). Thus, discovery is not exclusively a metacognitive process, nor is it exclusively an associative process. Both types of processes are crucial.

Although important, acquiring new ways of thinking is not the only way learning occurs. A second dimension of learning involves increasing reliance on the more advanced alternatives within the set of approaches that children already know. This is a more common vehicle of cognitive growth than is commonly recognized. For example, Lemaire and Siegler (1995) found that from the end of the first week of instruction to the end of the year, French children who were learning single-digit multiplication used the same set of strategies. The frequency of the most advanced strategy (retrieval of the answer from memory) increased considerably during this period, and the frequency of the least advanced strategy (adding one of the multiplicands the number of times indicated by the other) decreased considerably, but most children used the same set of strategies throughout the period.

Learning also can occur through increasingly precise fitting of strategy choices to the demands of problems and situations. Even if both the set of strategies and the frequency of use of each strategy remain the same, each strategy can be chosen increasingly often in those cases in which it is the best available alternative. Such changes also were present in the Lemaire and Siegler (1995) study. Over the course of the year, children fit their strategy choices increasingly precisely to the demands of problems and to the limits of their own knowledge. In particular, they used retrieval increasingly consistently on the easiest problems, problems on which they usually could retrieve the correct answer, and they increasingly limited use of repeated addition to the most difficult problems, problems on which retrieval was less accurate.

Another dimension along which learning occurs is improved execution of existing approaches. Even without changes along the other three dimensions, children's performance can improve greatly as they become increasingly skillful in executing each approach. In the Lemaire and Siegler (1995) study, for example, on those problems on which children retrieved answers to a given multiplication problem at all three times of measurement, percentage of errors decreased from 23% to 2%, and mean solution time decreased from 4 s to 2 s.

Data consistent with the overlapping waves model have been obtained across such varied tasks as toddlers' locomotor activity, preschoolers' arithmetic, and elementary and high school children's scientific experimentation (see Siegler, 1996, for a recent review of these studies). In all of these areas, children have been found to use multiple strategies at any given age, with variability existing within individual children as well as between children. In each area, children also have been found to rely increasingly on the relatively advanced approaches as they learn more about the domain. These same features are characteristic of adults' thinking and learning, as has been demonstrated in such domains as multidigit mental arithmetic, sentence-picture verification, and spatial reasoning (LeFevre, Sadesky, & Bisanz 1996; Marquer & Pereira, 1990; Newton & Roberts, in press).

These findings regarding children's and adults' learning have formed the basis for computer simulation models that use a common set of principles to account for cognitive growth from early childhood through adulthood (Shrager & Siegler, 1998; Siegler & Shipley, 1995). These simulation models suggest that the overlapping waves pattern arises through the workings of several learning processes. Problem-solving experience leads to an increasingly extensive database becoming associated with both strategies and problems. This database includes information on the speed and accuracy of each strategy on problems in general, problems with particular features, and specific problems. Experience using each strategy also leads to its execution becoming increasingly automatized. The increasingly extensive database on characteristics of strategies and problems makes possible increasingly refined choices among strategies and increasing reliance on the most advanced strategies. The increasing automatization of the strategies leads to increasingly fast, accurate, and effortless execution of strategies.

An interesting aspect of the most recent of these computer simulations, SCADS (Strategy Choice and Discovery Simulation; Shrager & Siegler, 1998) is that within it, discovery of new strategies arises through the interplay of associative and metacognitive learning processes. Automatization of execution of strategies leads to the freeing of cognitive resources that previously had been needed to monitor execution of the strategies. Some of these freed cognitive resources are used to search for redundant processing within existing strategies. If such redundancies are found, strategy discovery heuristics are used to generate potential strategies from the components of previous ones. These potential strategies are then evaluated against conceptual constraints on legitimate strategies in the domain. If the potential strategy is consistent with the conceptual constraints, it is tried. With each use of the new strategy, speed and accuracy characteristics become associated with it. This emerging database and the databases of the prior strategies together determine when the new approach is used. Thus, newly discovered strategies that are more effective than known alternatives are used increasingly.
and new strategies that are inferior to known alternatives come to be used less or not at all.

The fact that learning within the Shrager and Siegler (1998) model involves an interaction between metacognitive and associative processes is unlikely to be unique to the specific model or content domain. Rather, children's learning in most domains seems likely to reflect the interaction of associative and higher level processes. The reason why developmental psychologists could at one time focus on associative processes and at a later time on higher level processes is that both are important parts of cognition and learning. Focusing on one to the exclusion of the other yields a one-sided picture of cognitive growth.

Other models of children's learning, such as those constructed within dynamic systems theories (Smith, Thelen, Titze, & McLean, 1999; van Geert, 1998), differ in their particulars but they share with overlapping waves theory a number of assumptions about how learning occurs. Within both approaches, children learn by doing; learning occurs through performance. Another shared assumption is that variability is a central characteristic of the cognitive system, rather than reflecting measurement error. A third shared assumption is that learning comes about through many simultaneously changing aspects of the system rather than through any one central change that moves the system as a whole from one state to another. A fourth shared assumption is that a wide variety of constraints—anatomical, physiological, environmental, and cognitive—guide the form of learning.

Together, these theories converge on a new agenda for studying children's learning. Rather than trying to identify the age at which children develop a given capability, we would trace over time the set of approaches that they use. In other words, we would examine changing distributions of existing approaches as well as emergence of new ones. Another priority would be to examine changes that occur with age and experience in children's choices among alternative approaches, that is, in ability to flexibly adjust what they do to the demands of the problem and situation. A third priority would be to examine the circumstances surrounding new forms of behavior—what leads up to discoveries and how they are generalized once they emerge. Fortunately, all of these issues can be addressed through use of a particular method for studying children's learning, the microgenetic approach.

**MICROGENETIC METHODS FOR STUDYING CHILDREN'S LEARNING**

The central questions within prevailing theories influence, and are influenced by, prevailing research methods. Standard cross-sectional and longitudinal methods, which sample the thinking of children at different ages, fit well with theories that emphasize such questions as "When do children understand ___?" and "What is the developmental sequence of knowledge states by which children come to understand ___?"

In contrast, if a central theoretical question is "Through what processes do children learn ___?", standard cross-sectional and longitudinal methods are less useful. The problem is that within these methods, observations of emerging competence are spaced too far apart in time to yield detailed information about the learning process. They lack the temporal resolution needed to indicate how change occurs.

This is where microgenetic methods are particularly useful—for answering questions about learning processes. As noted by Siegler and Crowley (1991), such methods have three main properties:

1. Observations span the period of rapidly changing competence.
2. Within this period, the density of observations is high relative to the rate of change.
3. Observations are analyzed intensively, with the goal of inferring the representations and processes that gave rise to them.

The second property is especially important. Densely sampling changing competence during the period of rapid change provides the level of temporal resolution needed to understand the learning process. If children's learning usually proceeded in the most straightforward way possible, such dense sampling of ongoing changes would be unnecessary. We could examine their thinking before and after changes occurred, identify the shortest path between the two states, and infer that children moved in a beeline from the less advanced one to the more advanced one. Such beelines are the exception rather than the rule, however. Cognitive changes involve regressions as well as progressions, odd transitional states that are present only briefly but that are crucial for the change to occur, generalization along some dimensions from the beginning of learning but lack of generalization along other dimensions for years thereafter, and many other surprising features. Simply put, the only way to find out how children learn is to follow them closely while they are learning.

**FOUR LESSONS FROM RECENT STUDIES OF CHILDREN'S LEARNING**

In the past decade, microgenetic methods have been used to study an increasing range of populations and content domains: infants' learning of reaching and
locomotor skills (Adolph, 1997; Thelen & Ulrich, 1991), preschoolers’ learning of attentional strategies and number conservation (Miller & Aloeise-Young, 1996; Siegler, 1995), elementary schools’ learning of memory strategies, mathematical principles, analogical reasoning, and pictorial representation (Alibali, 1999; Bjorklund, Coyle, & Gaulney, 1992; Chen & Klaht, 1999; Golden-Meadow, Alibali, & Church, 1993), and adolescents’ and adults’ learning of scientific experimentation skills (Kuhn, Garcia-Mila, Zohar, & Andersen, 1995; Schauble, 1996). Despite varying theoretical predispositions of the investigators, diverse content domains of the tasks, and widely separated ages of the children studied, the descriptions of learning that have emerged from microgenetic studies are strikingly similar. Consider four of the most consistent findings.

Change is gradual. In the large majority of studies of children’s learning, researchers have found change to be gradual. Older, less powerful ways of thinking about a task often continue to be employed for a long time after newer, more advanced ways of thinking about it are also available (Kuhn, 1995; Schauble, 1990, 1996; Siegler, 1994). Change is especially likely to be gradual in cases where the new approach is not hugely advantageous relative to existing approaches. This is often the case, because early approaches tend to be reasonably effective. Counting from one generally yields correct solutions to arithmetic problems (Siegler & Jenkins, 1989), unsystematic scientific experimentation strategies often allow identification of causal relations (Schauble, 1996), inefficient map drawing strategies usually get the ambulance to the hospital (Karmiloff-Smith, 1979), and so on. Even when a new approach eventually offers large advantages, it may not do so at first, because children cannot execute it effectively (Bjorklund, Miller, Coyle, & Slawinski, 1997; Miller & Seier, 1994). When a new way of thinking is much more effective than any previous approach, it sometimes becomes dominant quite quickly (Alibali, 1999; van Geert, 1998), but more often change is gradual.

Discoveries follow success as well as failure. A second consistent characteristic of children’s learning is that children discover new strategies when they have been succeeding on a task as well as when they have been failing (Karmiloff-Smith, 1992; Miller & Aloeise-Young, 1996; Siegler & Jenkins, 1989). Necessity sometimes is the mother of invention, but at other times, invention occurs without external pressure. Children frequently generate novel strategies after having solved several problems correctly and on problems that they have previously solved correctly. This finding is in accord with the everyday observation that many discoveries arise in situations with minimal external demands: taking a shower, driving to work, taking a walk, and so on.

Early variability is related to later learning. A third common finding from microgenetic studies is that the initial variability of thinking is positively related to the subsequent rate of learning. In many studies, the greater the initial variability, the more likely that children will generate useful problem solving strategies and abandon ineffective older ones (Alibali & Golden-Meadow, 1993; Graham & Perry, 1993; Perry & Lewis, 1999; Siegler, 1995). Several specific forms of initial cognitive variability have been found to be positively related to subsequent learning: number of strategies used over a set of problems, frequency of shifting from one strategy to another within a single trial, frequency of self-corrections and deletions in verbal descriptions of strategies, and frequency of expressing one strategy in speech and another in gesture on a single trial.

Not all types of variability are positively related to learning. For example, Coyle and Bjorklund (1997) found that changes in strategy use from one trial to the next were negatively related to percent correct recall. This may have reflected children adopting a win-stay-lose-shift approach, in which they tended to shift strategies from one trial to the next when recall on the earlier trial was incorrect but tended to maintain the same strategy if it yielded correct recall. Consistent with this possibility, McGilly and Siegler (1989) found that strategy shifts on a serial recall task occurred more often following incorrect recall than following correct recall. More generally, because cognition is variable in so many different ways, it will be important to examine the relation between initial variability and subsequent learning using a variety of measures of both variability and learning.

Discoveries are constrained by conceptual understanding. A fourth consistent finding is that discovery of new strategies is guided by conceptual understanding of the domain (Coyle & Bjorklund, 1997; Gelman & Gallistel, 1978; Granott, 1993; Schauble, 1990, 1996). The novel strategies that children attempt generally make sense; they are not generated via blind trial and error. Newly generated strategies do not always yield correct solutions to the problems that elicited them, but they usually are reasonable efforts in that direction. It is important to note that there certainly are times when children generate conceptually flawed strategies. These can arise either through children having an incomplete understanding of the goals that legitimate strategies in the domain must meet or through the situation requiring children to generate an answer even though they do not know any plau-
possible strategy for doing so. Despite these exceptions, it is striking how often newly discovered strategies conform to the principles underlying legitimate strategies in the domain.

The consistent phenomena that have arisen from microgenetic studies have given rise to a set of intriguing proposals regarding the processes that produced the changes. To account for the persistent use of nonoptimal strategies despite more effective strategies being known, the construct of utilization deficiency has been proposed (Bjorklund, Miller, Coyle, & Sławinski, 1997; Miller & Seier, 1994). To account for discoveries being made in the absence of external pressure, the SCADS computer simulation progressively frees attentional resources as it gains experience executing existing strategies, thus activating strategy discovery heuristics (Shrager & Siegler, 1998). To account for positive relations between initial variability and subsequent learning, investigators have focused on the ways variable behavior reveals the possibilities inherent in the task environment (Neuringer, 1993; Stokes, 1995). To account for how children discover legitimate addition strategies without ever trying illegal ones, the idea of goal sketches has been proposed (Siegler & Jenkins, 1989), tested and supported through empirical experiments (Siegler & Crowley, 1994), and formally specified as a part of the SCADS model (Shrager & Siegler, 1998).

The connection between the microgenetic studies and the detailed ideas about mechanisms is no coincidence. Microgenetic studies yield sufficiently detailed information both to suggest ideas about how the data were generated and to rule out many otherwise plausible alternative accounts. To cite one such case, prior to the first microgenetic study of single-digit addition, the prevailing model (Groen & Resnick, 1977) was that children first solved such problems by counting from one (the sum strategy), then by counting from the first addend, and then by counting from the larger addend (the min strategy). That is, children were hypothesized first to solve problems such as $3 + 5$ by counting “1, 2, 3 — 1, 2, 3, 4, 5 — 1, 2, 3, 4, 5, 6, 7, 8”), then by counting “4, 5, 6, 7, 8,” and then by counting “6, 7, 8.” Although this model seemed plausible, a microgenetic study of development of single-digit addition disconfirmed it; children discovered the min strategy without ever having counted from the first addend. Conversely, the microgenetic study indicated that shortly before children discovered the min strategy, they began to use a different transitional approach that had not been hypothesized. This was the shortcut sum strategy; children using it would solve $3 + 5$ by counting “1, 2, 3 — 4, 5, 6, 7, 8.” In retrospect, the shortcut sum strategy made sense as a transitional approach. As in the less advanced sum strategy, children count from 1; as in the more advanced min strategy, children count each number only once, rather than twice as in the sum strategy. However, it was not until the microgenetic study of addition that the shortcut sum strategy was identified as a transitional approach. The example illustrates how microgenetic data constrain ideas about transition mechanisms, both in the negative sense of ruling out otherwise plausible accounts and in the positive sense of documenting the path of change.

**LEARNING AND DEVELOPMENT**

As noted earlier, the movement away from studying children's learning was fueled in large part by the view that learning and development were fundamentally different processes. Recent studies of children's learning provide reason to rethink this conclusion. As Kuhn (1995) commented:

In the 1960s and 1970s, development was contrasted to a simplistic, nonrepresentational conception of learning that has little relevance today. Modern research has made it clear that learning processes share all of the complexity, organization, structure, and internal dynamics once attributed exclusively to development. If the distinction has become blurred, it is not because development has been reduced to "nothing but" learning, but rather because we now recognize learning to be more like development in many fundamental respects (p. 138).

Findings from cognitive developmental neuroscience provide additional support for the view that learning and development are both similar and inseparable. Regardless of whether the change is species-typical, such as development of stereopsis in response to binocular exposure to patterned light, or idiosyncratic, as when a rat learns to turn left in a maze to obtain food, synaptic changes involve a cycle of proliferation and pruning (Greenough, Black, & Wallace, 1987). First, there is a burst of formation of new synaptic connections; then, experience prunes away those synapses not involved in subsequent processing. The terms "learning" and "development" are used differently, with development referring to changes that are more universal within the species, that occur over longer time periods, and that occur in response to a broader variety of experiences. At the level of process, however, the two have a great deal in common.

Increasing our focus on children's learning will yield a more comprehensive understanding of development; it also may yield valuable educational applications. It is no secret that many children do not learn
well in school. Rigorous developmental analyses of how children learn—and fail to learn—reading, writing, and mathematics may produce better understanding of the learning difficulties and may contribute to better programs for remedying them. This is already starting to happen. Geary (1994) identified a number of contributors to mathematics disability: limited early exposure to numbers, poor working memory capacity for numerical information, and limited conceptual understanding of arithmetic operations and counting. Similarly, Griffin (in press) formulated a neo-Piagetian analysis of how children learn basic numerical concepts and applied it to the task of helping low-income first graders master these basic concepts, with impressive results.

Microgenetic analyses of learning may prove especially helpful for indicating how instructional procedures exercise their effects, and thus for designing more effective future instructional procedures. For example, recent studies indicate that asking children to explain why correct answers are correct and why incorrect answers are incorrect produces greater learning than only asking them to explain why correct answers are correct (Siegel, in press). Microgenetic analyses of the learning process indicated that part of the reason for this advantage was that asking children to explain both correct and incorrect answers led to their adopting new strategies that were more widely applicable, ones that would generate correct answers not only on the original problem set but also on types of problems that were not initially presented. The practical implication is that when students have a tendency to respond to instruction by adopting overly narrow strategies, it may be particularly useful to ask them to explain both why correct answers are correct and why incorrect answers are incorrect. More generally, as these examples illustrate, the rebirth of children’s learning promises not only to create a more exciting field of cognitive development but also to help children learn.

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REFERENCES


