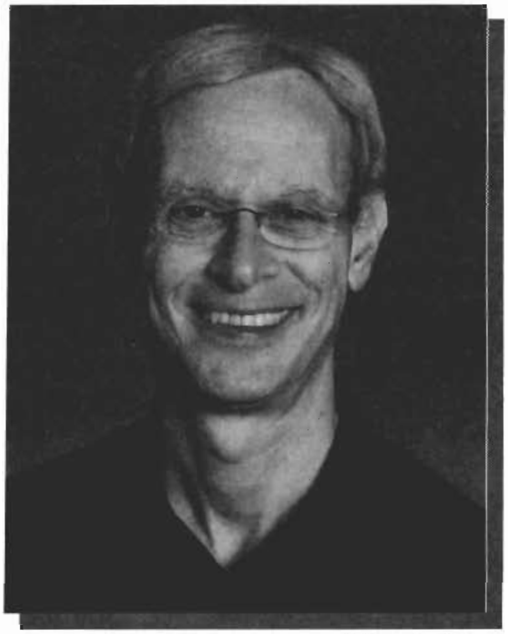

Photo by Ken Andreyo

Robert S. Siegler

Award for Distinguished Scientific Contributions

Citation

"For distinguished theoretical, empirical, and methodological contributions to the study of cognitive development. Robert S. Siegler's superb, detailed, and extensive empirical analyses of the emergence and refinement of children's cognitive strategies in a wide variety of domains—ranging from elementary mathematics to complex scientific reasoning—have elucidated the nature and mechanisms of developmental change. His highly original overlapping waves model of strategy choice, in which variability is understood to be a core feature of developmental change, has been widely influential. He has also been one of the most articulate proponents and effective practitioners of the microgenetic method in developmental research."

Biography

Robert S. Siegler was born in Chicago in 1949. His parents, Allen and Ilse Siegler, had come to the United States a decade earlier, having left Nazi Germany to avoid being killed. The family's experience was to have a major formative influence on Siegler's life, creating a strong motivation to achieve so that the sacrifices, made by those who got out and those who did not, would not have been in vain.

Siegler's interest in how change occurs started early. His favorite subject in school was history, and the part of history that he liked best was thinking about how the pasts of different countries influence their presents and likely futures. In contrast, his becoming a psychologist was largely fortuitous. He was an economics major for most of his undergraduate years at the University of Illinois, and he probably would have continued in that field if not for his simultaneously taking a particularly boring economics course and Harry Hake's fascinating course on perception.

After graduating, Siegler enrolled in the State University of New York at Stony Brook's graduate program in clinical psychology. By the end of his first year, however, he had decided to focus on cognitive development. The decision was made when his advisor Robert Liebert and he tried to teach a five-year-old liquid quantity conservation through modeling of correct answers and explanations. Siegler went into the experiment convinced that he would demonstrate that this kook, Piaget, was dead wrong: Of course a five-year-old would know that pouring water into a different shaped glass did not change the amount of water. Siegler was surprised when the little girl said that the tall thin glass had more water, but he was shocked when the girl maintained her stance despite Liebert—a large, imposing man with a deep booming voice—repeatedly telling her that she was wrong. At this point, Siegler's career path was set; anything that could motivate a five-year-old to defy Bob Liebert merited serious study.

Liebert's main line of research examined the effects of televised violence on children's aggression. However, he was generous enough to advise a student whose interests lay elsewhere. One of the most important lessons that Liebert conveyed was that researchers should address big issues and conduct experiments that seem interesting and important to them rather than trying to repeat, with small modifications, what others already have done. He said, "If it makes sense to you, it'll probably make sense to others." This was good advice.

Siegler and Liebert's research (e.g., Siegler, Liebert, & Liebert, 1973) focused on the development of problem solving and learning, particularly in the domains of mathematics and science. These have continued to be the core areas of Siegler's research. However, the way that Siegler approached these topics changed greatly after he became an assistant professor at Carnegie Mellon University in 1974. Newell and Simon's path-breaking research on problem-solving work was a revelation to him. Their thinking, together with Marv Levine's blank-trials procedure, which Siegler had encountered at Stony Brook, stimulated Siegler's (1976, 1981) first substantial research contribution, the *rule-assessment approach.* This approach was based on two ideas: (a) that children solve many problems by consistently adhering to specific rules and (b) that these rules can be identified by presenting problems for which each rule generates a unique pattern of correct answers and errors. Siegler spent most of the next five years demonstrating the applicability of the rule-assessment approach to a wide variety of concepts and problems, among them conservation of liquid quantity, solid quantity, and number; time, speed, and distance; the balance scale; shadows projection; probability; fullness; and living things. His re-

Vol. 60, No. 8, 767–778 DOI: 10.1037/0003-066X.60.8.767

search during this period also focused on developmental differences in learning and on the *encoding hypothesis*, the idea that young children's frequent failure to learn more advanced rules from relevant experience was a result of their failing to encode relevant information.

In the early 1980s, Siegler noticed a phenomenon quite different from the consistent adherence to a single rule that he had observed in the rule-assessment studies. When preschoolers and young elementary schoolchildren added or subtracted single-digit numbers, they used a variety of different strategies rather than a single consistent approach. Sometimes they counted from 1, sometimes they counted from the larger addend, sometimes they retrieved the answer from memory, and so forth (Siegler & Shrager, 1984). This conclusion was met with considerable skepticism, because it differed sharply from Piagetian and information-processing models, both of which postulated that individuals generally use a single strategy at a given time. However, the conclusion gained general acceptance when subsequent research replicated the findings on strategic variability and explained mathematically why incorrect single-strategy models could fit data produced by multiple strategies reasonably well (Siegler, 1987). The research also indicated that variable strategy use is adaptive, both in the sense that strategies are used most often on problems for which the strategies are most effective and in the sense that overall accuracy and speed are greater when children are allowed to use multiple strategies than they are when children are limited to a single approach (Siegler & Lemaire, 1997). Both strategic variability and adaptive choice have proven characteristic of many tasks: addition, subtraction, multiplication, word identification, spelling, serial recall, tic-tac-toe, matrix completion, locomotion, number conservation, biological classification, and even one- and two-year-olds' tool use (Chen & Siegler, 2000).

The findings on strategic variability raised the issue of how children discover new strategies. Siegler and Jenkins (1989) used a *microgenetic* approach to address this problem. They presented children with experiences that seemed likely to trigger strategy discoveries, videotaped the children's performance, and assessed strategy use on a trial-by-trial basis. This allowed them to identify the first trial on which a child used a new strategy and to analyze what led up to the discovery and how it was generalized beyond its initial context. This and other studies using the microgenetic method have revealed many aspects of the change process: that new strategies are frequently discovered following the success, rather than the failure, of existing approaches (e.g., Siegler & Crowley, 1991); that generalization of new strategies tends to be slow and uneven (Siegler, 1995); that goal sketches often guide the discovery process in useful directions (Siegler & Crowley, 1994); that strategy discoveries can be unconscious (Siegler & Stern, 1998); and that discovery of new, superior approaches can be promoted by asking children to explain why an outcome occurred (Siegler, 2002). Microgenetic data also have provided a basis for computational models that both choose adaptively among strategies and discover new approaches (Shrager & Siegler, 1998; Siegler & Araya, 2005).

Siegler's most recent empirical studies have focused on why children find estimation so difficult and what can be done to improve their skill. The research has revealed a surprising source of many children's difficulty—reliance on logarithmic rather than linear representations of numerical magnitudes. Kindergartners and many first graders rely on logarithmic representations of small numbers; second graders, third graders, and some fourth graders rely on logarithmic representations of larger numbers (Siegler & Booth, 2004; Siegler & Opfer, 2003). Older children rely on linear representations on the same tasks. In the absence of feedback, estimation is highly stable, but feedback on problems on which logarithmic and linear representations are maximally discrepant promotes rapid improvement (Opfer & Siegler, 2005).

These findings and models culminated in the *overlapping waves* theory of cognitive development (Siegler, 1996, in press). The theory posits that at any given time, individual children typically use a variety of approaches to solve a class of problems, that the more effective approaches become increasingly common with age and experience, that children frequently discover new approaches, and that children choose adaptively among the approaches they know. The theory also provides a framework for analyzing cognitive change in terms of its path, rate, breadth, source, and variability.

Siegler attributes much of his success to stimulating and generous colleagues and students. He credits David Klahr for providing innumerable insights and useful advice over their 30 years together at Carnegie Mellon. Karen Adolph, Martha Alibali, Judy DeLoache, John Flavell, Iris Levin, James Staszewski, and Elsbeth Stern stand out as other exceptional colleagues. Among Siegler's graduate students and postdocs, especially significant contributions have been made by Dean Richards to the rule-assessment research; by Patrick Leamire, Kate McGilly, Bethany Rittle-Johnson, and Jeff Shrager to the strategy-choice studies; by Zhe Chen, Kevin Crowley, Eric Jenkins, and Matija Svetina to the strategy-discovery studies; by Roberto Araya, Chris Shipley, and Jeff Shrager to the computational modeling; and by Julie Booth, Norman Brown, Elida Laski, and John Opfer to the estimation research. Working with them has been a singular privilege.

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Children's Learning

Robert S. Siegler
Carnegie Mellon University

A new field of children's learning is emerging. This new field differs from the old in recognizing that children's learning includes active as well as passive mechanisms and qualitative as well as quantitative changes. Children's learning involves substantial variability of representations and strategies within individual children as well as across different children. The path of learning involves the introduction of new approaches as well as changes in the frequency of prior ones. The rate and the breadth of learning tend to occur at a human scale, intermediate between the extremes depicted by symbolic and connectionist models. Learning has many sources; one that

Editor's Note
Robert S. Siegler received the Award for Distinguished Scientific Contributions. Award winners are invited to deliver an award address at the APA's annual convention. A version of this award address was delivered at the 113th annual meeting, held August 18–21, 2005, in Washington, DC. Articles based on award addresses are reviewed, but they differ from unsolicited articles in that they are expressions of the winners' reflections on their work and their views of the field.