Howard Gardner

What we do & don't know about learning

Suppose that we were commissioned to create a museum of learning. I don't mean a stuffy, hands-off collection of old manuscripts or films, but rather a state-of-the-art exploratorium that displayed the full spectrum of learning types and, in vivid form, everything that is known about learning.[1] Suppose, further, that we had a budget for consultants and were able to hire the seven experts whose essays are collected here. Presumably we would have in mind a number of guiding questions, among them: What examples of learning should we include? How should we conceptualize this enterprise? What progress has taken place in our understanding of learning in the last century or so, and how can these revolutionary insights inform the education of future generations? Finally, what puzzles remain?

In all probability our museum's first displays would show humans learning: infants crawling, walking, talking; toddlers engaged in rough-and-tumble or imaginative play; youngsters (or oldsters) at school, learning their 3Rs and going on to master the disciplines and perhaps engage in interdisciplinary work. Casting our net more widely, we might exhibit a child learning to play a musical instrument, an apprentice working alongside a master builder, a medical student attending rounds, a recruit in the military, a physically injured person recovering the ability to walk, a victim of a stroke learning to talk or reason again.

Casting our net more widely still, to encompass the full range of learning among animals, our museum might include exhibits of sea slugs that learn to move in certain directions while avoiding others; fish that 'imprint' on certain physical forms and trail after these privileged forms throughout development;

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1 This supposition is not idle. At Harvard Project Zero, a research group concerned with learning with which I have been affiliated since 1967, we are planning to construct such a museum – at first virtually, ultimately in bricks and mortar.

rats that learn their way around complex natural and man-made mazes; pigeons that can play ping-pong, trace missiles, and recognize human beings in photographs; chimpanzees that can use sticks to wipe off termites or to hide treasures from their fellow chimps, and that seem able to learn some language-like systems.

We will also need to create displays that show the organic structure of the brain and explain how learning takes place at microscopic levels: in regions of the brain (like the hippocampus), in neural column networks (like those involved in recognizing lines of different orientation), and even in single nerve cells that form synaptic connections to other nerve cells and have those connections bolstered or weakened as a result of experience.

And our museum will also have to exhibit machines that learn and think, so to speak: smart machines that can play (and improve in) chess, that can understand much of natural language, interact with human beings, and engage in scientific problem solving.

As the range of exhibits and displays suggests, our imaginary museum, like the group of consultants it has retained, reflects a wide range of theories about learning and about the appropriate level at which to analyze and understand the phenomenon.

Still, as we plan our museum, it is important to step back and to provide both a definition and a little history. As a rough and ready approximation, learning occurs under the following condition: An organism or entity represents a certain amount of information or data at time X; at time Y it can represent new or additional or transformed information that brings it closer to a goal – either a goal of the entity's own choosing or a goal that is intended by another entity, which we may designate a teacher or trainer. Such a formulation allows us to distinguish learning experiences from the sheer accumulation of mud on a tire, on the one hand, and from a computer program that may accomplish amazing feats, but always in precisely the same way, on the other.

From studies of preliterate cultures and naive children, we can with some confidence delineate the major folk theories of learning: Human beings learn by observing others who are more knowledgeable and by imitating, implicitly or explicitly, what they do; asking questions of and listening to what more knowledgeable individuals say; practicing a skill and noting its improvement; receiving clear rewards or punishments that signal which course of behavior should be pursued and which should be eschewed. In literate cultures, the theories of learning expand to include the reading of texts and the taking of classes; and there are of course more idiosyncratic theories that call attention to the learning potential embodied in dreams, drugs, and deities. It is interesting to note the extent to which more formal theories of psychology and pedagogy venture beyond these 'commonsense' views of the learning process.

Before there was a formal psychology or biology of learning, it was philosophers who addressed issues of knowledge – perception, learning, memory, and the like. With Greek and Roman thinkers as background, the philosophers of the Renaissance and the Enlightenment carved out positions that continue to serve as points of orientation today. Descartes took a strong mentalistic position, arguing that the mind operated according to its own principles and that it came stocked with innate ideas. We see echoes of this perspective in the writings of Noam Chomsky and Jerry Fodor, self-identified nativists. The British empiricists, led by Locke, took an opposing perspective, according to which the mind was initially a blank slate; experience etched ideas onto the slate and these ideas become associated with one another. Twentieth-century behaviorists like the Russian physiologist Ivan Pavlov, the American psychologist B. F. Skinner, and the 'learning theorists' portrayed here by Jerome Bruner subscribed to this empiricist point of view.

In the eighteenth century, two new perspectives on learning took hold. Immanuel Kant described the basic epistemological categories – time, space, number, causality – that human beings necessarily imposed on their sensations and perceptions. Individuals did learn from experience, but that experience was necessarily apprehended in temporal, spatial, and causal ways. The Kantian problematic had a great effect on the research program of twentieth-century Swiss developmental psychologist Jean Piaget, who sought to describe the development in infants and young children of these categories of experience. Piaget was also influenced by the writing of his countryman Jean-Jacques Rousseau, who discerned genius in the mind of the child and believed that knowledge should be allowed to unfold within, rather than be imposed didactically upon, the child.

Studies of learning were influenced enormously by the rise of evolutionary thinking, chiefly emanating from the insights of Charles Darwin and, to a lesser extent, other British scholars like Alfred Wallace, Thomas Huxley, and Herbert Spencer. These writers all stressed the continuities between human beings and other animals, and the importance of mental capacities that allowed individual organisms to survive until reproduction. To be sure, instincts were crucial for lower organisms. But it was the vertebrates – and especially mammals – capable of problem solving and planning who emerged as victors in the struggle for survival. As soon as the implications of Darwin's writings became clear, his way of thinking came to dominate both the theories and the empirical work of scientists interested in learning.

The first generation of modern scholars of learning did not shrink from attending to the more complex forms of reasoning in human beings and other primates. But beginning in the early twentieth century, the territory of learning was largely ceded to those researchers who stressed the continuity of learning across the animal kingdom; avoided issues of language, consciousness, and higher-order ratiocination; and strove to explain any intellectual achievement in the most parsimonious and reductionist fashion. Interestingly, this was true not only for those experimentalists who worked primarily with rats and pigeons (the two most common 'model organisms') but also for those, like Edward Lee Thorndike, who studied the acquisition of skills in school-age children. For the first half of the twentieth century, this approach to learning held sway.

And indeed, it might still hold sway today had it not been for the development of high-speed computers and the complex programs that have permitted these electronic entities to compute and solve various kinds of human-scale problems. Once it became clear that computers could mimic human thought processes and – in the view of many – bootstrap themselves over time to a higher level of performance, scientists could no longer withhold such intellectual competences from human beings. Thus was born the cognitive revolution, an important intellectual movement among whose forefathers were the computer scientists Herbert Simon and Marvin Minsky, the linguist Noam Chomsky, and the psychologists George Miller and Jerome Bruner. I view the cognitive revolution as a contemporary interdisciplinary effort to provide scientific answers to long-standing epistemological questions, such as our present consideration – the nature of learning, why it is possible, how it occurs.

In a broad sense, all of the consultants to our museum – the contributors to this issue of *Dædalus,* and the majority of current workers on issues of learning – are offspring of this intellectual revolution of fifty years ago. They recognize the relationship between the long-standing philosophical agenda sketched above, on the one hand, and discoveries in psychology, linguistics, anthropology, neuroscience, cognitive science, and other relevant disciplines, on the other. And they believe that progress is being made in understanding the nature of various kinds of learning, though they may differ on how best to describe that learning and the nature of that progress.

Now that I've surveyed the historical context to our current understanding of learning, it is timely to suggest the major dimensions against which to evaluate the specific contributions of our consultants – as well as those of some other consultants who might have been retained.

Two dimensions seem particularly useful: the learning of species or entities to which these consultants compare human learning; and the type and extent of reductionism entailed in their efforts to explain all manner of learning. Continuing in the tradition laid out by Darwin and his successors, Daniel Povinelli and Michael Tomasello find it productive to delineate the nature of learning in chimpanzees. While both have documented the impressive capacities of chimpanzees, they elect in their essays here to focus on the fault line between chimpanzees and children. Povinelli claims that chimpanzees are incapable of abstract thought; that all of their achievement is the result of observations of concrete objects and events. Tomasello documents that chimpanzees have only the most meager capacities to imitate models, to infer the motives of others, and to transmit any kind of cultural knowledge. The chimpanzee emerges in their accounts as an organism that is incredibly skilled at making use of the information at hand, but that is unable either to conceptualize what is not present or to make use of the incidental knowledge attained by other individuals in its group. Here lies the huge fault line that separates chimpanzees from human children, who from early on can engage in pretend play, imitate elders, and rapidly assimilate the knowledge that earlier generations have accumulated.

Not represented in this collection but worthy of note is the recent claim by primatologist Marc Hauser and his colleagues Noam Chomsky and Tecumseh Fitch that they have identified a crucial capacity that is absent in nonhuman primates: the capacity for recursion.[2] Bonono apes are able to master language-like strings of symbols, provided that the syntax of the string does not depend on the capacity to embed one unit within another. For instance, an ape may appreciate the logic in the proposition "Mommy sleeps," but could be completely stymied by an expression like "Baby said that Mommy sleeps," let alone "Daddy said that Baby said that Mommy sleeps."

2 Marc Hauser, Noam Chomsky, and Tecumseh Fitch, "The Faculty of Language: What Is It, Who Has It, and How Did It Evolve?" *Science* 298 (2002): 1569 – 1579.

In her essay here Alison Gopnik focuses on the characteristics of young children, but she brings to bear an entirely different comparison group. Like several other contemporary developmental psychologists, Gopnik finds it useful to think of the child in comparison to the working scientist – a worker rather like herself. In making this analogy, Gopnik revisits a theme introduced decades ago by Jean Piaget (as well as themes first articulated by the philosopher of science Thomas Kuhn in his discussion of paradigmatic scientific revolutions). However, Gopnik goes well beyond Piaget, who tended to emphasize the limitations in childrens' thinking and the discontinuities between child tinkerer and adult scientist. She argues that, like scientists, very young children are capable of putting forth theories, carrying out experiments, observing the experiments of others, and discerning statistical patterns. In an accompanying essay, Susan Carey characterizes the conceptual growth from child to scientist as a bootstrapping operation; only through such self-constructing operations can children proceed, for example, from early intuitions about quantity to a full-blown sense of number.

Possibly because they are philosophers, Patricia Churchland and Clark Glymour are less concerned with the specifics of experiments involving infants or chimpanzees. Churchland discusses learning at the level of individual nerve cells, while Glymour describes the powerful operations that can be carried out by high-speed computers.

From my vantage point, the key issue their juxtaposed essays raise is the question of reductionism. To put it sharply, can human learning and thinking be adequately reduced to the operations of neurons, on the one hand, or to chips of silicon, on the other? Or is something crucial missing, something that calls for an explanation at the level of the human organism?

As I read her essay, Churchland stresses the importance of understanding the nervous system and chides those philosophers who do place the same value on it. But she does not feel the need to dispense with a psychological level of explanation. For most of his essay, Glymour embraces a tougher-minded reductionism: we should stop trying to solve problems that are too complicated for us and instead turn them over to those ever smarter computers. But in the end, Glymour acknowledges that the problems solved by computers are ones that human beings have formulated and that, at both ends of the process, we need human judgment after all.

As one who surveyed the cognitive sciences in some detail twenty years ago,[3] I am very impressed by the knowledge that has accumulated in the past few decades. Thanks to theoretical and empirical researchers like those represented here, we know a great deal more about the nature of early learning and understanding in human beings, and can point with far greater precision to the ways in which humans differ from their closest biological relatives. Our accumulating knowledge of the nervous system is even more impressive, and the bridges between cognitive science and neuroscience are sturdier. The accomplishments of computers are also striking; and while some of these accomplishments are achieved by methods quite remote from those used by Homo sapiens, we are beginning to have software and hardware that in important respects learn in ways that resemble our own

3 Howard Gardner, *The Mind's New Science: A History of the Cognitive Revolution* (New York: Basic Books, 1985).

learning. In fact I have heard that good chess masters now study computer games and learn new strategies from those inanimate models. Ultimately, of course, debates similar to those between the rationalists and the empiricists in the eighteenth century, and between the learning theorists and the Gestaltists in the first half of the twentieth century, are still being waged. Yet, as Jerome Bruner indicates in his essay, the current debates are conducted in much more sophisticated ways.

But as one who seeks to build a museum of learning, I am struck by the limitations, reflected in the essays collected here, of the still evolving cognitive sciences. Let me mention the principal ones.

First of all, these disciplines almost always deem the scientific mind as the proper model of human thought. The claim that all cognition, learning, development, and intelligence are best represented by those of the scientist was Piaget's great contribution, and also his weakness. And we see his sentiments in most of the essays here. But human thinking and learning is achieved as well by artists, musicians, politicians, businesspeople, inventors, religious leaders, and dreamers – we must understand their forms of learning and the ways in which they may differ from the cognition of the theoretical physicist or the benchtop chemist.

Second, the instances of learning that are most frequently examined typically take place over brief periods of time: nanoseconds in the case of computers, milliseconds in the case of nerve cells, an hour or less in the case of most experimental trials. Yet the forms of human thought that are most valued often require the investment of months or even years. What of the learning involved in Albert Einstein's coming up with the theory of relativity; Marcel Proust's penning *À la recherche de temps perdu*; Andrew Wiles's solution of Fermat's theorem; or Mahatma Gandhi's creation of peaceful nonviolence; or, indeed, Ramon y Cajal's studies of the nervous system, or John von Neumann's formulation of the nature of computer programming? Even the high-speed computers that can handle far more variables than ordinary mortals can do not illuminate the nature of original artistic, scientific, or political thought.

Moreover, the contributions of cognitive science to schooling – the chief institution devoted to learning – remain modest. As one who spends his life at a school of education and has devoted much time to school reform, I could not help but be struck by the virtual absence here of any reference to schools, formal teaching, the 3Rs, and the scholarly disciplines – in short, the realms that most individuals think of nowadays when they think of learning. Part of the explanation for this is undoubtedly that schools are very complex institutions and the processes of learning that are supposed to take place there over months or years are difficult to capture in scientific research.

Still, I think that more can be said about how our current understanding of learning might influence education, as well as the obstacles that make such applications difficult. In my own work I have recently focused on two lines of research. The first outlines the various misconceptions that readily arise in early childhood and that considerably complexify the mastery of the disciplines. It turns out that young children readily embrace creationist accounts of the origin of the species, a phenomenon that makes difficult the learning of evolutionary theory; embrace Aristotelian accounts of the behavior of physical matter, which render the mastery of Newtonian physics problematic; and readily embrace one-dimensional accounts of historical and political events, thus making it difficult to appreciate complex and multicausal accounts. Recognition of the early emergence and dogged persistence of these misconceptions is an essential component of effective pedagogy. Teachers must directly confront these misconceptions and give students ample opportunities to air their understandings and misunderstandings, to discover where they are inadequate and where they require revisions.[4]

I have also collected evidence against the contention that intelligence is a single, all-encompassing human capacity. I favor an alternative account: that all human beings possess a range of intelligences and that we differ from one another in our intellectual profiles. Throughout most of history, educators have ignored this possibility and have taught subjects in one way – thereby inevitably favoring students who are strong in linguistic and logical ways of thinking. It is possible to reverse this uniform approach, and so reach more students, by presenting materials in a multitude of ways and giving students options in how they may convey their own understandings.

Alas, even if we had exquisitely detailed and powerful theories of learning, this would be no guarantor that they would be adopted widely in schools. As David Olson argues in his recent book, schools are bureaucratic organizations that respond principally to political pressures and institutional imperatives.[5] This, in short, is the reason that politicians in America talk incessantly about test scores and international comparisons, and rarely if ever mention what has been learned about learning. Independent schools have somewhat greater latitude in what they prescribe but they are by no means immune from these social pressures. Only in homeschooling or individual tutoring can the student readily benefit from our growing understanding of learning. And only when ways are found to bridge the gap between the knowledge being accumulated by scholars and the typical operations of schools in the nation-state will the pipeline between research and practice be opened.

Finally, I believe that there is also a conceptual gap that needs to be addressed – both by our consultants and by our hypothetical museum of learning.

That gap concerns the fact that human beings are social, cultural, and historical creatures as much as we are neurological, psychological, and computational creatures. We evolved to do many things well – but we did not evolve to create calculus or write the U.S. Constitution or compose classical music or invent airplanes and the pill. Nor could anyone have anticipated, even fifty years ago, the civil rights revolution, or the feminist revolution, or the fall of communism, or the proliferation of nuclear weapons, or the rise of the World Wide Web in an increasingly globalized civilization. Yet somehow individuals growing up in the early twenty-first century must be able to master these bodies of

4 See Howard Gardner, *The Unschooled Mind* (New York: Basic Books, 1991) and *The Disciplined Mind* (New York: Penguin Putnam Books, 2000).

5 David Olson, *Psychological Theory and Educational Reform* (New York: Cambridge University Press, 2003).

knowledge and cope with these events of historical significance. Little in our sciences of learning addresses issues of this scale; our cultural, historical, and literary studies do not make much contact with our scientific approaches; an interdisciplinary span across these broad disciplinary terrains still eludes us.

In short, there will be a great deal of interest on display in our hypothetical museum of learning. But there will also be a large number of empty rooms – for there is still so much that we have to learn about learning.