Vannevar Sets the Stage

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The National Academy of Education at 50

Members Reflect

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Vannevar Sets the Stage

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This essay is a personal account of some events in my life associated with the establishment and evolution of the National Academy of Education (NAEd). I begin with some comments on U.S. science policy and conclude with a brief account of my own research on the educational process.

The Bush Report

Near the end of World War II, President Roosevelt—recognizing science's remarkable contributions to the war effort—asked his science advisor, Vannevar Bush, to define a plan for science in the post-war era. That request led to Bush's report *Science: The Endless Frontier* (Bush, 1945). What was the nature of that report? No summary could do justice to Bush's masterful analysis, but essentially he made three principal arguments about the future of the U.S. scientific enterprise. First, he argued that most aspects of research and development (R&D) are the responsibility of the private sector. However, he also recognized that market mechanisms discourage the private sector from investing adequate funds in basic research. This recognition led Bush to his second argument: ensuring support for basic research in the post-war period should be the responsibility of the federal government, because the enormous benefits to society at large justify the investment. He believed that basic research should be

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conducted in the universities of the nation, rather than in government laboratories. As the institutions responsible for the nation's basic research, universities had pride of place in Bush's vision of the research enterprise. Third, he argued that decisions about which university research projects should receive government funding should be made via a peer-review process.

The Bush report remains to this day the single most important document on U.S. science policy ever written and a landmark for federal legislation. Before World War II, the federal government provided virtually no funds for research at universities; the very concept was viewed as radical. In the post-war period, the government committed itself to becoming the principal sponsor of scientific research to be conducted primarily at universities. It was an extraordinary reversal of direction.

The Bush report led to the establishment of the National Science Foundation (NSF) and the reorganization of the National Institutes of Health (NIH) and other federal agencies to support extramural research. Initially, the flow of funds for research moved at a slow pace and was primarily focused on the physical and biological sciences and engineering. However, when the Soviets successfully launched the satellite Sputnik in 1957, America began to question its leadership in science. It responded with a massive increase in funding for science to include the behavioral and social sciences. In addition, there was a sense that the United States had fallen behind the Soviet Union in science education, particularly in grades K–12. The response was a series of large-scale curriculum projects principally funded by NSF. These projects enlisted some of America's most famous scientists who worked collaboratively with educators to develop curriculum. The projects proved to be successful, but it soon became evident that the body of research to guide the effort was insufficient. The curriculum projects and related federal ventures in education led to a major expansion of the educational research enterprise that involved more funding for research and fellowships to attract individuals of outstanding ability. The field of educational research blossomed during this period and involved a mix of scientists from various disciplines, including those whose first identity was as an educational researcher.

Formation of the NAEd

To ensure the future of educational research, it was time to establish an academy of individuals elected on a national/international basis for outstanding scholarly and research contributions relevant to education. In the early 1960s, Francis Keppel, U.S. commissioner of education, began an exchange with Ralph Tyler, director of the Center for Advanced Study in the Behavioral Sciences, about a way to evaluate the state of U.S. education. That exchange was followed by a series of committee meetings under the sponsorship of the Carnegie Corporation of New York that laid the foundation for the National Assessment of Educational Progress and increased federal funding for educational research. During this period it became evident that an organization such as the National Academy of Sciences (NAS) could play a facilitating role. John Gardner, president of the Carnegie Corporation, then wrote a letter inviting a leading group of individuals involved in education to form the NAEd, and Carnegie provided start-up funding to make it a reality.

In the 1970s, when I was NSF director, I brokered a number of meetings between the NAEd leadership and Philip Handler, NAS president, with the goal of including the NAEd under the umbrella of the NAS/National Research Council. These talks were cordial, and Handler always expressed high regard for the NAEd members. However, there were too many obstacles to overcome, not the least of which was the precarious state of the NAEd finances and the absence of any endowment. The NAEd's current president, Michael Feuer, has engaged in similar discussions with the NAS leadership in recent years. There has always been a desire to cooperate, but not as yet to join forces.

Evolution of Computer-Assisted Instruction

My involvement with educational research began in the late 1950s as a newly appointed member of the faculty at Stanford University; it was an unusual joint appointment involving the Department of Psychology, School of Education, School of Engineering, Statistics and Applied Mathematics Laboratories, and Institute for Mathematical Studies in the Social Studies. In those days my main research interest involved the formulation and testing of mathematical models for learning and conditioning in both humans and animals. Patrick Suppes, a charter member of the NAEd, was my colleague at Stanford. He was a professor of philosophy with a special interest in mathematical logic and the philosophy of science. He was a leading authority on the role of formal models in the development of scientific theories. Suppes was one of those individuals from another discipline who joined the NSF effort to develop the new mathematics curriculum; his own work was on mathematics in grades K–3. Given my interests in models of memory and learning, his work on the role of models in science, and his newly formed interest in how young children acquire mathematical skills, we collaborated on a number of studies.

In 1962, Suppes and I received a grant from the Carnegie Corporation to support the use of a computer to conduct psychological experiments. Of special interest was the idea of teaching reading and mathematics to young children under computer controls with the capability of individualizing the instruction. We purchased a PDP-1 computer manufactured by Digital Equipment Corporation; it was one of the first transistorized computers. We quickly had six terminals running on a time-sharing system and were busing kindergarten and first-grade students to our laboratory at Stanford. Encouraged by our initial success, we applied and received a $1 million grant from the U.S. Office of Education (this was before the U.S. Department of Education existed). In those days $1 million grants were rare; even the physics community took note.

Our plan was to develop a computer assisted instruction (CAI) system to teach reading and mathematics to culturally disadvantaged, K–3 children. Our group at Stanford undertook the design and implementation of what became known as the IBM 1500 Instructional System. The 1500 system was installed at a school in East Palo Alto and went into operation in the fall of 1967. The 1500 system was housed in two trailers on the school parking lot. One trailer housed the computer system; the other trailer, 16 student terminals. Each student terminal had a cathode-ray tube (CRT), a typewriter keyboard, a light pen to touch a point on the face of the CRT, a projector with a capacity of 1,000 color images, a set of earphones with a microphone, and pre-recorded audio messages that could be "randomly" accessed (this was before digital audio was commercially available). Suppes had responsibility for developing the mathematics curriculum, and I had responsibility for the reading curriculum.

By the end of 2 years, approximately 400 students had received a major part of their daily instruction in reading and mathematics under computer control. As the first installation of its kind, the system received considerable national attention; more than 3,000 visitors per year had observed students at work on the system. More importantly, significant gains in student achievement had been demonstrated. A description of our work with the 1500 system is available in an article titled "Computerized Instruction and the Learning Process" (Atkinson, 1968).

The 1500 system permitted us to individualize the learning process, but not to the extent we wanted. The IBM 650 drove the system, which was the first computer to be widely adopted by American universities; today's iPhone has 10,000 times the computing power of the IBM 650. Furthermore, the system's cost was prohibitive, and locating the computer at the school site had major disadvantages. Fortunately, while working with the 1500 system, we continued to expand the PDP-1 system housed at Stanford. The student terminals were simpler: a low-cost display device, a typewriter keyboard, and a headset supported by digital audio that was truly random access. We soon had about 40 terminals in several Stanford buildings connected to the computer by phone lines. It was not a big step to connect to schools at remote sites. We restructured the reading and math programs for the Stanford system, and by 1967 about 3,000 students were receiving daily instruction in seven nearby elementary schools and in locations as distant as McComb, Mississippi; Morehead, Kentucky; and Washington, DC. The system and its effectiveness are described in an article titled “Teaching Children to Read Using a Computer” (Atkinson, 1974; Fletcher & Atkinson, 1972).

As the Stanford system was upgraded and enhanced, it was possible to experiment with a wider range of courses. Suppes developed a program in logic that he used to supplement his regular Stanford lecture course in introductory logic. My group developed a course in computer programming using the BASIC computer language, which was widely used by Stanford graduate and undergraduate students and at two local community colleges (Barr, Beard, & Atkinson, 1975). These courses were adaptive in two ways: (1) the sequence of instruction varied as a function of a student’s performance history and (2) the CAI program could self-modify as more students completed the course and their data were used to update estimates of parameters that specified problem difficulty (Atkinson, 1976).

A principal goal of our CAI research was to experiment with different approaches to optimizing student performance. For some topics, we were able to formulate mathematical models of the learning process and then use methods of control theory to make moment-by-moment decisions about what should be learned next to optimize the student’s performance. Several parts of the K–3 reading program and of the foreign language vocabulary programs provided elegant examples of this approach. In other cases, the “optimal” schemes were not optimal in a well-defined sense, but they were based on our intuitions about learning and relevant laboratory experiments. Elsewhere, I have used the term “theory of instruction” to describe the issues involved in using a theory of learning, formal or not, to develop an optimal program of instruction (Atkinson, 1972a, 1972b; Atkinson & Paulson, 1972; Chant & Atkinson, 1978; Groen & Atkinson, 1966).

During fall 1974, I was invited to be a visiting professor at Rockefeller University for the academic year 1975–1976. Part of my plan for the year was to write a book reviewing our research on CAI. The tentative title was *Theory of Instruction*. However, at the last minute my world changed. I was recruited to NSF, expecting to spend my sabbatical year in Washington, DC. I never returned to Stanford. My career as an active researcher ended at that time (Atkinson, 1999).

Since I left the field of educational research, the development of CAI has continued, and there are beautiful examples using psychological theory to individualize instruction. A variety of commercial entities, both large and small, have promoted the use of CAI in schools and universities and for training personnel in the military and corporate sectors. The deployment of CAI has not been as rapid as I predicted in a 1969 article in the *Proceedings of the National Academy of Sciences of the United States of America*, but it has been substantial (Atkinson, 1969). Suppes was the most persistent and long-term contributor to the field. His efforts were truly remarkable, both in the development of new programs and in the detailed experimental evaluations of student performance. The Stanford University Online High School is an example of what he accomplished. This online, fully accredited, diploma-granting program for grades 7–12 serves students around the world. It has been in operation for over a decade with excellent results. Unfortunately, Suppes passed away in November 2014. He was a giant in the world of academia, and his death is a great loss to the field of educational research.

The world of CAI underwent a total transformation in 1994 with the advent of the Internet, which offers an instruction platform with a rich multi-sensory surround and a virtually unlimited computing capacity. Wireless communication has also contributed to this transformation; the flexibility of not being tied to the Internet by a cable makes a substantial difference in education. Since 1994 MOOCs (Massive Online Open Courses) and related efforts have been introduced. That work is interesting, but the key to success is individualizing instruction, which requires a theory of the learning process.

Conclusion

I conclude with a comment about education policy and the NAEd. From my personal and professional journeys, I have learned many lessons about the involvement of researchers in the formulation of policy. The NAEd plays a special role, as an organization focused on building and sustaining connections between scholarship and action, cultivating future researchers oriented toward the improvement of educational policy and practice, and providing a home for nonpartisan explorations of the basic and applied sciences of teaching and realities. Given the imperative of investing wisely in the development of human capital, it is more important than ever that our NAEd be a prominent and visible player.

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