Hands On!

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BY GEORGE HEIN

Science Education for a Thriving Democracy

"In order to save our democracy we've got to educate the people who vote." — JERROLD ZACHARIAS[1]

"Science Education for a Thriving Democracy" is an appropriate rallying cry for any vision for education in the United States. Our nation prides itself on championing democracy, and public education has been the most powerful tool available for forging our democratic society and sustaining it for more than 200 years. Early republican writings emphasize the importance of free, public education for the fledgling democracy. Jefferson considered his work in establishing free education as his most important contribution to building the United States.[2] (CONTINUED ON PAGE 4)

feature continued from cover

George Hein addresses participants at a symposium celebrating TERC's 40th anniversary

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Madison's famous letter to W. R. Berry, applauded the Kentucky legislature for its "liberal appropriations" for a general system of education and argued

A popular Government, without popular information, or the means of acquiring it, is but a Prologue to a Farce or a Tragedy… it is better for the poorer classes to have the aid of the richer by a general tax on property, than that every parent should provide at his own expence [sic] for the education of his children, it is certain that every Class is interested in establishments which give to the human mind its highest improvements, and to every Country its truest and most durable celebrity.

Learned Institutions ought to be favorite objects with every free people. They throw that light over the public mind which is the best security against crafty and dangerous encroachments on the public liberty."[3]

This faith in the power of public education for all and massive support for a truly inclusive public education system have repeatedly stirred the nation and brought dramatic opportunities for previously underserved sectors of the population. The Morrill Act of 1862 creating "land grant" colleges was such a bold move. It has provided affordable higher education to millions of citizens. Another was the GI Bill of Rights (Servicemen's Readjustment Act of 1944) that opened up college educations for returning GI's who might otherwise never have had such opportunities.

It seems particularly important today to reaffirm the connections between our commitment to education and allegiance to democracy since this essential feature of our American social contract is increasingly ignored. The primary argument for supporting public education and science education has been reduced to an economic one: that it is necessary for us to produce more scientists and engineers to maintain our competitive advantage in the global economy.[4]

Our modern efforts to renew and revitalize science education began after World War II with similar calls to protect our global dominance, specifically to counter Soviet advances that threatened our economy and our way of life. But the scientists and educators who provided us with modern science education in public schools subscribed to the bolder and broader original U.S. vision for the role of education in a society: they viewed education, especially in science, as essential to sustaining our democratic society. A similar rallying call is necessary today. We can learn from the giants of the 1950s and 60s—on whose shoulders we inevitably stand—as we reach for better education for all.

We Didn't Talk About "Failing" Schools

In reflecting on my own experiences as a young scientist who left the laboratory to devote himself to science curriculum development, as well as looking at historic documents, I've been struck by two major themes. One is the way public views on education and political rhetoric have changed during the last 40 years. The other is that there is a mythology about science education in the 1960s that doesn't match what occurred. These two themes are related; we reinterpret history through the prism of current understandings.

"In order to get people to be decent in this world, they have to have some kind of intellectual training that involves knowing [about] Observation, Evidence, the Basis for Belief." — JERROLD ZACHARIAS

First, there's a matter of language: we didn't talk much about "reform" and about "failing" schools. That view of education is much more recent. The goal was to improve education because it was "inadequate," not because it was "failing." The American Association for the Advancement of Science (AAAS) organized a series of conferences for scientists and educators in 1960-61 that helped generate support for new elementary science projects. The final report summarizing the conference begins

There is an urgent need for major improvement in the science instruction offered in elementary and junior high schools. In the hope of finding ways to effect this improvement, three conferences of teachers and scientists, all sponsored by AAAS but conducted independently, recently considered the following aspects of science instruction: present practices and materials; recent efforts to create new courses for senior high schools and recent experiments in teaching young children.[5]

I remember the excitement of joining the staff at the Elementary Science Study at the Education Development Center (EDC) in an era seeking improvement rather than blame. I was part of a national effort to make science education richer and more interesting for children, bring about change in public schools, and, therefore, improve social conditions for everyone in the United States.

Jerrold Zacharias was the most significant scientist who initiated the effort to improve K-12 science education in the United States starting in the 1950s. We need only look at what he had to say to recognize that his motivation encompassed more than a commitment to keep the United States economically and militarily strong. Zacharias had successfully guided the Radiation Lab at the Massachusetts Institute of Technology (MIT) during World War II, earning the respect of both scientists and government policy advisors.[6] After the war, Zacharias remained in Boston, took up teaching and research at MIT and started consulting for the growing technology industry. He had a full life including experimenting with novel teaching methods, government consulting, running a lab, and participating in profitable technological enterprises. But in 1955, he decided to switch his major attention to science education improvement.[7]

Zacharias' new interest coincided with the emergence of the National Science Foundation (NSF), founded in 1950, as a first and major federal government agency to support science research and science education. It was part of the NSF mandate to stimulate and improve science education at every level. Through his strong government ties and the support of MIT's administration, he was able to launch an MIT spin off that later became EDC. The United States was concerned with the production of new scientists and the increase in scientific productivity in this country, but Zacharias saw the problem on a much grander scale.

The reason I was willing to do it [PSSC] was not because I wanted more physics or more physicists or more science; it was because I believed then, and I believe now, that in order to get people to be decent in this world, they have to have some kind of intellectual training that involves knowing [about] Observation, Evidence, the Basis for Belief.[8]

"We have stunted an entire generation of students because people believed it was important to simply enumerate objects, rather than understand what the object was in the first place."
— Neil deGrasse Tyson, Keynote Address, TERC Symposium

It was largely a matter of social conscience, I believe, that motivated us [scientists] to school work. As scientists, we seek evidence before we try to create order, or orderliness, and we do not expect, nor even hope for, complete proof… We live in a world of necessarily partial proof, built on evidence, which, although plentiful, is always limited in scope, amount and style. Nevertheless, uncompleted as our theories may be, they all enjoy, in a sense, the benefits of due process of law. Dogmatism cannot enter, and unsupported demagoguery has tough time with us. A Hitler or a McCarthy could not survive in a society which demands evidence which can be subjected to examination, to reexamination, to doubt, to question, to cross-examination. It may be this lesson that gives us a missionary zeal.[9]

 continued from page 5

Free public education for a fledgling democracy.

Zacharias' first venture into K-12 education was the creation of a high school physics course, PSSC. That course, like all the other secondary school science curricula developed elsewhere at that time—CHEM Study, CBA and BSCS—was developed as a general secondary school science curriculum, not for advanced students or what today would be an AP course.

A few years after the wave of secondary school curricula (and attendant workshops for teachers) were begun, the growing community of scientists and educators engaged in these projects realized that improvement was also needed at the elementary and junior high school level. A major effort to provide science education for all students was launched. Again, social goals predominated in the thinking and motivation of those who were involved in the second phase. The report from the AAAS conferences mentioned earlier was clear that more and better science education was necessary for all students in public schools and that the purpose was not to produce more scientists, but to educate children to become better citizens.

As part of general education, science should constitute a regularly scheduled part of the curriculum in all grades. The purpose is to equip all persons for life in a scientific and technological society. If all of the more than 35 million pupils in elementary and junior high schools can be given good experiences in science all will have a good start towards scientific literacy.

More than anything else the purpose of science in general education is to develop a more complete view of life in a scientifically oriented world culture.[10]

Individual projects were also explicit in stating that they were developing curriculum and teacher workshops for a general audience of all students, not only for the preparation of future scientists.

My own experience working in curriculum development in the 1960s was without doubt that we were attempting to introduce programs that would serve all children, not any special group, and that the main purpose of introducing inquiry science into classrooms was not only to provide a grounding in science, but to provide experience with the processes of science that could be applied to all subjects. We saw science education, essentially missing from the elementary school, as the easiest way to revolutionize elementary school practices. All other subjects—reading, arithmetic, social studies—had well-established methodologies and any effort to change them needed to compete with existing texts, teaching methods and curricula. The beauty of science was that it hadn't been taught and was now seen as important. Therefore it could be used to shake up the schools and have all teaching focus more on thinking skills than on rote learning of decontextualized material. Supporting our efforts to develop materials for all schools, considerable development work was carried out in schools that served the poorest students and those in working class communities.

There is another myth about the earlier curriculum projects, namely that they "failed." It's difficult to know what might be the evidence for this belief, since we could hardly expect to find 40-year-old curricula still in use. Today's elementary and secondary science education is profoundly influenced by the work carried out 40 years ago. The gen-

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eral conception that science should be taught through inquiry, and, more important, how this could be carried out in the classroom—the hallmark of all the programs and methods currently encouraged by both the NSF and all the relevant professional associations—was essentially invented and implemented on a national scale by the science education improvement efforts of 40 years ago. The materials used today in elementary science, and the profusion of kit-based programs, are a direct consequence of the earlier work. Another domain where the science materials of the 1960s are actively used is in science museums and science centers, a growing informal educational community that did not exist 40 years ago.

Quality Takes Time and Money

I cannot overemphasize the difference in rhetoric about schools in the 1960s compared to today. Federal assistance to schools was minimal before passage of the National Defense Education Act of 1958, during Eisenhower's administration.[11]

In 1965, the year of TERC's founding, the groundbreaking Elementary and Secondary Education Act was passed under President Johnson as part of his broader program of the War on Poverty. Johnson went to Texas and signed the bill with his former grade school teacher at his side. The language is mainly positive, with the emphasis on funding programs (this includes Head Start, Title I and other compensatory programs), reaching underserved children and helping to redress past inequities. In contrast, NCLB is focused more on regulatory provisions and includes mandatory testing, expanded options for parents, and an emphasis on particular teaching methods, especially for reading. The general public discourse about schools—that they are failing and need to be "reformed," that is, fixed by applying business methods, including "bottom-line" accountability (whatever that business term may mean when referring to schools) simply didn't exist forty years ago.

Most significant for curriculum development and professional development is what these changes in policy and public attitude mean for working in classrooms and with teachers. The pressure on teachers today to follow detailed lesson plans and conform to specific curricular goals is enormous. Any request that they experiment with new materials is asking them to take a tremendous risk. That certainly wasn't the case when we were working in schools in the 1960s. I remember a two-month period during which my colleague Joe Griffith and I went to an elementary school in Watertown, Massachusetts, twice a week. We explored a unit on prehistoric tools that included starting fires by various primitive means. The children were only occasionally successful in coaxing actual flames from the bow drills or flints and white cedar shavings we supplied, but we certainly generated a huge amount of smoke! I can't imagine being allowed to do this today. But you don't get good curriculum without the freedom to take risks and try activities that don't work out. The vital pedagogic truism that you have to make mistakes to learn is very difficult to implement today.

Not only did the earlier science improvement efforts benefit from a more confident climate, they were supported more generously. The typical new curriculum went through several trial phases of increasing complexity: a first trial in a class was followed by an alpha version in multiple classrooms, then a beta version distributed nationally, and only then was a gamma version published commercially and sent to classrooms with the expectation that it, too, might be revised after some use. More recent projects usually leave out one or more of these development phases.

We had time, and we also had money. "Quality costs," Zach used to say. The NSF was willing to pay for quality and, I believe, they got it. For an example of what was spent on projects, PSSC

(far left) Symposium panelists Darren Wells, winner of a Presidential science teaching award, George Hein, and Cary Sneider, Director of Programming for the Museum of Science, discuss the current state of science education (left) Megan Bang, a research fellow at TERC, presenting her research on science learning among American Indian students (right) Mish Michaels, CBS4 meteorologist, discussing the TERC/Museum of Science WeatherWise exhibit

received $1.8M in start-up costs before the October 1957 launch of sputnik. That's equivalent to 12.8M in today's dollars. The expenses were high because the course audaciously proposed extensive use of film, which was relatively expensive. It also produced spectacular pedagogic material. An unforgettable example is *Frames of Reference*, which begins with one physicist upside down and the other right side up. The two argue about who is in each position. CHEM Study, a straightforward high school chemistry course, received $2.8M from NSF in the 1960s, (equivalent to $16.2M today) and ESS received $7.6M ($44M today).

Another difference in approach during that period was the concept that it was essential to produce multiple curricula and multiple approaches to pedagogy so that districts, schools and teachers would have choices. The NSF emphasized that it did not want to dictate either what should be taught or how it should be taught. Instead, it purposely supported a range of materials and methods.

Perhaps the greatest difference between then and now is that the materials were produced and used in school before the introduction of "standards" and the now ubiquitous high-stakes tests at many grade levels. The nation has moved from benchmarks, guidelines and frameworks published by professional organizations and sometimes states, to detailed written documents; couched in language that accommodates multiple-choice test questions. The documents become long lists of facts to learn or nebulous platitudes about science, and make both inquiry-based curriculum development and professional development difficult.

A Vision for Education

Starting 50 years ago the United States launched a major national effort to improve science education, to expand its scope among the school population, and to increase the quality of instruction, both through funding new curricula and supporting professional development for teachers. The high point of this effort was probably 40 years ago, when a dozen secondary school projects from astronomy to geography were available; middle school was rich in new programs ranging from social studies to earth science; and there were 8-10 elementary programs under development. Most of the individual programs no longer exist; they are out of date or simply weren't strong enough to survive in the competitive world of textbook adoption.

What has survived and totally changed the landscape of science teaching is that, at least to some extent, science is taught at all levels. Even if science education is not universal nor always taught as we wish it would be, at least there are districts that have demonstrated through years of experience that inquiry science, using materials and engaging children in meaningful activities that lead to richer and stronger understanding of science, is possible on a large scale in U.S. classrooms.

We need to incorporate these successes into our vision and consistently emphasize that while more science education can be good for the economy, it has a larger role to play in educating all children to learn to question, challenge and base decisions on evidence. We know that active science education can be part of school. It can be implemented and assessed on a national scale to lead to a more scientifically literate society and most important, can strengthen our democracy.

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2 See Lee, G. C. (1961) Crusade Against Ignorance: Thomas Jefferson on Education, New York: Teachers College Press. 160-167.

3 Kurland, P. B. and R. Lerner (eds.) (1986) The Founders' Constitution, Chapter 18, Document 35, Chicago: University of Chicago Press.

4 See, Rising Above the Storm: Energizing and Employing America for a Brighter Economic Future (2006), released by the NAS Committee on Prospering in the Global Economy of the 21st Century.

5 AAAS, (1961) Science teaching in elementary and junior high schools, Science, 133, No. 3469, (June 23, 1961)) 2019-2022+2024.

6 Arthur Nelson was one of the illustrious staff that worked on the roof of building 6 developing radar, one of the Lab's major achievements.

7 For a detailed and very readable biography of this extraordinary man, see Goldstein, J. S. 1992. A Different Sort of Time, Cambridge, MA: MIT Press.

8 Quoted, in Goldstein, p. 164-165. Goldstein points out that "Observation, Evidence, the Basis for Belief" were Zacharias' mantra, "He always capitalized them, they were as fundamental to him as breathing."

9 J. Zacharias, Research scholars and curriculum development, ESI Quarterly Report, Summer Fall 1965, p. 101-104, from an address to the Modern Language Association, NY, 12/29/64.

10 AAAS (1961) op. cit.

11 Eisenhower's response to concerns about sputnik was not to ask for massive military build up but to increase federal support for education including a five-fold increase in the NSF budget for educational activities. See Goldstein, pp. 170-171.