Science Education 1965 and 2005: Myths and Differences[1,2]

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Introduction

It's an honor and a pleasure to serve on this panel and to participate in this symposium. We are assembled today to forge a vision for the future for science education in the US. This is, obviously, not the first time thoughtful people have come together for this purpose, but renewal is necessary to sustain important initiatives. It's too easy to continue activities without sufficiently examining whether they actually support larger purposes.

Science Education for a Thriving Democracy is an appropriate rallying cry for any vision for education in the US. We pride ourselves on championing democracy, and public education has been our most powerful tool, first proposed early in the history of the republic and evolving into a powerful, unique system over more than 200 years. Remember that Jefferson considered his work in support of education to be his greatest achievement. 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[3] and even attacked.

Speakers today have been asked to address their vision for science education, what they see as essential for supporting science education for a democratic society. I've been asked to sketch, very briefly, what it was like 40 years ago, during the time when Arthur Nelson founded TERC and the United States was in the midst of a major effort to improve science education, and, also, to suggest what we can learn from that experience.

I'm in the fortunate position to remember the 1950's and '60's—a rich and exciting period in our country's history—from personal experience. So I'm going to combine personal memory with a look back at the record. What were the motivations and visions that inspired scientists and educators to work to improve science education in the period after the Second World War?

In reflecting on my own experiences and looking at some historic documents, I've been struck by two major themes. One is a mythology now about science education 40 years ago that doesn't match what actually occurred then. The other is that I'm impressed, and saddened, by the change in public views and political rhetoric over these 40 years. These two themes are related; we reinterpret history through the prism of current understandings[4].

Myths about 1960's Science Education Improvement

First, there's a matter of language: we didn't talk much about "reform" or about "failing" schools. That view of US education is much more recent. The goal was to *improve* science education (and education in general) because it was "inadequate," not because it was "failing."

For example, consider the following quotation from a significant report[5] summarizing a series of three invitational conferences for scientists and educators sponsored by the National Science Foundation and organized by AAAS in 1960-61 that helped generate support for new elementary science projects. It 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.
> The conferences reached the following conclusions: instruction in science should be a regular part of the curriculum from kindergarten through grade 9 (and beyond, but the conferences considered only these grades); a major effort to improve science instruction in these grades should be undertaken; and this effort should involve improving both course materials and classroom teaching.

The language of "improvement" is used throughout: there's no suggestion that what has happened before is responsible for failures. Instead, there is a sense that the nation can do better. This important distinction goes to the heart of a difference in outlook between the 1960's and today. I remember the excitement of joining the staff at the Elementary Science Study at EDC and feeling that I was part of a group who, along with many others across the country, were going 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 US.[6]

But to return to myths, current discussions of 1960's science education improvements, besides mislabeling them as early "reforms," frequently describe them inaccurately as:

a). Motivated primarily by desire for the US to maintain its political and economic strength—to beat the Russians in the Cold War, especially after the shock of Sputnik

b) To produce more scientists, because we needed them for the goal above, and

c) Therefore, to introduce into schools science curriculum (and presumably teacher training through workshops) for the most advanced students, for the elite population that might become scientists. What's currently called the "pipeline" approach (or pipeline problem, depending on how one views it).

The current focus on the economic competitive reasons for more science, as described in the National Academies report last month—which acknowledges Thomas Friedman's arguments on this subject of the need for more expenditure on science for global competitive reasons, is typical of current writing. I don't intend to suggest that similar economic arguments were never considered then, or that competition with the USSR for economic, political and military advantage played no role in procuring funding for science education, But other arguments were also put forward in the 1960's and the motivation for leaders in this movement incorporated a larger vision for strong science education in the schools. Certainly, the curricula and teacher training workshops were intended for all students and all teachers.

We need only look at what Jerrold Zacharias, generally recognized as the most significant person in the initiative to improve K-12 science education in the United States, had to say. Zacharias had successfully guided the important Radiation Lab at MIT during the war, earning the respect of both scientists and government policy advisors. 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] After the war, Zacharias remained in Boston, took up teaching and research at MIT and started consulting for the growing technology industry around Boston. His full life included 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.[8]

Zacharias' new interest coincided with the emergence of the 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, Zacharias was able to launch an MIT spin off, similar to many "Route 128" companies (except that it was a non-profit), that later became EDC. What motivated him to change his career direction dramatically and then use his prestige and connections to persuade so many others to join the effort to improve science education? The NSF, and the government in general, were certainly concerned with the production of new scientists and the increase in scientific productivity in this country, and Zacharias wasn't ignorant of this need. But that wasn't his primary motivation, or that of many who joined and followed after him. He saw the issue on a much grander scale. It's worth quoting him directly.

> 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.[9]

> 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 a 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.[10]

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— CHEM Study, CBA and BSCS— were developed as general secondary school science courses, not for advanced students or what today would be AP courses.[11]

They were designed primarily for students who were college bound because these were the adolescents then (as now) who enrolled in secondary school physics and chemistry. BSCS deliberately developed three versions of its course so that it could be used with a wide range of students.

There was a gap in science courses for non-academic track children. It was this educational gap, the lack of any appropriate science and technical education for many students, that inspired Arthur Nelson and his colleagues to imagine a new form of technical education: skills for the emerging technologies. TERC was founded "to improve the quality and availability of job-relevant technical and occupational education in the United States and abroad."[12] Early curricula focused on training in newly emerging fields such as preparation for work in biomedical equipment technology, laser and electro-optics technology and highway safety occupations, as well as projects geared towards educational opportunities for physically handicapped students and economically disadvantaged minority groups (using the language of the time.)

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. If more general social goals motivated at least some of those who worked on secondary school science curricula, they certainly dominated the thinking and motivation of those who were involved in the second phase. A significant effort to provide science education for *all* students was launched.

The report from the 1961 AAAS conferences mentioned earlier made it 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.[13]

It went on to emphasize that the real purpose of science in the early years is to introduce scientific ways of thinking.

> 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.

Individual projects were also explicit in stating that they were developing curriculum—and the attendant professional development workshops for teachers—for a general audience of all students, not (certainly not only) for the preparation of future scientists. For example, IPS *Intermediate Physical Science*, a middle school science curriculum developed under the leadership of Uri Haber-Scheim at EDC, states in its Preface:

> This is a year-long course in introductory physical science. Its purpose is to give all students a beginning knowledge of physical science and to offer some insight into the means by which scientific knowledge is acquired. The course is designed to serve as a solid foundation both for those students taking later courses in physics, chemistry and biology and for those taking no further natural science in high school.[14]

IPS ends with the following Epilogue

> As this course comes to an end you may ask yourself, "What have I learned this year in science?" We hope you will think of several things, some specific and some of a more general nature." . . .Contrary to what you may have expected, science does not deal with absolute truths. The specific facts we find in the laboratory, such as masses, lengths, melting points, and solubilities, are all subject to the limitations of our measurements. The useful generalizations based on these measurements, the laws—such as the conservation of mass and Boyle's law—also have their limitations. If this is the case in science, where we can perform experiments under controlled conditions and repeat them as many times as we wish to assure ourselves of the results, how careful must you be about the facts and generalizations you encounter in your daily life? If your introduction to science has made you a more critical reader, a more careful observer, and a sharper thinker, your work during the year was worthwhile.[15]

And this was not a unique EDC approach; it was shared by all the elementary curriculum projects. In their detailed description of the origins and development of SCIS, a project at UC Berkeley, Robert Karplus and Herbert Thier began with a general description of the "Innovations in science education" (note, not "reforms") focusing on elementary school. It's clear that these innovations are intended for all children.

> The elementary school classrooms must become laboratories as well as study halls, and the school environment must be used for field studies as well as for recreation. . . this idea is not at all new in science education. . .Unfortunately, it was never implemented on a significant scale. By and large, what existed in the name of elementary science was a reading program.[16]

My own experience working in curriculum development in the 1960's was that we were developing programs that would serve all children, not any special group. Our goal was a dramatic improvement in the entire elementary school curriculum and teaching style based generally on progressive education principles. The primary purpose of introducing inquiry science into classrooms was not only to provide grounding in science and not necessarily to nurture future scientists, but more broadly to provide experience with the processes of science so that all children could apply them to all subjects. We saw science education, previously essentially missing from the elementary school,[17] as the easiest way to revolutionize elementary school practices. All other subjects—reading, arithmetic, social studies—had well established methodologies already 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, was now seen as important (or so we hoped) and could therefore be used as a means to shake up the schools and have all teaching focus more on thinking skills than on rote learning of decontextualized material. Our goals may have been naïve, but they were definitely not geared towards filling the pipeline for future scientists or intended only for academically inclined students. 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. I personally worked regularly in Boston at the old (and later the new) Trotter School and the Andrews in south Boston. I know that Karen Worth, (here in the audience,) taught in Harlem with the new materials, as I did at a nearby community center on 111th Street. EDC established a "model schools" project in Washington DC public schools using ESS materials. Other projects tested materials and promoted them in similar communities.

Finally, another myth about the earlier curriculum projects is that they "failed."[18] But that is no more true for these particular innovations of the 1960's and earlier than it is for any materials that would now be 40 years old. Considering the commercial initiative to have students constantly buy new texts as well as rapid changes in knowledge, in what subject (at any level) does one find curricula in use today that were developed 40 years ago? A few, like BSCS, have been revised repeatedly and are still in print; others don't exist in their original form but can clearly be discerned in later modulations that rely on the education theory and materials developed earlier. The idea that science should be included in the curriculum for every child K-12, although still not the norm, comes from that time. The tenets that science should be taught through inquiry, and, more important, how this could be carried out in modern classrooms, the hallmark of all the programs and methods currently encouraged by both the NSF and all the relevant professional associations, were essentially developed and implemented on a national scale by the science education improvement efforts 40 years ago.[19]

Then and Now, Some Differences

I've already alluded to the different climate in the rhetoric about schools.[20] I don't think that can be overemphasized. The idea of federal assistance to schools was essentially unheard of before passage of the National Defense Education Act of 1958, during Eisenhower's administration.[21] 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 inequity. 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 may mean when extrapolated to schools) simply didn't exist forty years ago.

There changes in fundamental policy and public attitude are significant for curriculum development and professional development—the kind of activities that TERC and Museum of Science carry out with schools; what it means to work in classrooms with teachers. The pressure on teachers today to follow detailed lesson plans and conform to specific curricular goals is enormous, so that any request that they try something new, something unproven or experiment with new materials is asking them to take a tremendous risk. That wasn't the case when we were working in schools in the 60's. I remember a two-month period during which my colleague Joe Griffith and I went to an elementary school in Watertown twice a week and explored a unit on prehistoric tools, including ancient ways to start that a fire for cooking. The children were only occasionally successful in coaxing actual flames from the bow drills or flints and white cedar shavings they used, but we certainly generate a huge amount of smoke! I can't imagine being allowed to do this today both because of the class time required and the content of the unit. But you don't get good curriculum without exploring activities that don't work out, and having the freedom to take risks. The vital pedagogic truism that you have to make mistakes to learn, which can only be taught by example, is very difficult to implement today.

Not only did the earlier science improvement efforts benefit from the more confident climate of that time, they were simply supported more generously than are projects today. The typical curriculum material 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 usually published by the projects themselves and distributed nationally or at least regionally, and only then was a gamma version published commercially, 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. Here are a few examples of what was spent on projects. PSSC received $1.8M in start up costs *before* the October 1957 launch of sputnik. That's equivalent to $11.9 in 2004 dollars. The expenses were high because the course audaciously proposed extensive use of film, which was relatively expensive. It also produced spectacular pedagogic material. For example, *Frames of Reference*, which begins with one physicist upside down and the other right side up, arguing about which is in each position, is unforgettable. CHEM Study, a relatively straightforward high school chemistry course, received $2.8M from NSF, ($11.9 in 2004 terms) in the 1960's and ESS received $7.6M from NSF, equivalent to $41.7 today during the same period, after some start up funds from foundations.

Another difference between that period and the present was the recognition that it was essential to produce multiple curricula and multiple approaches to pedagogy, so that school districts, schools and teachers would have choices. The federal agencies, both NSF and U.S.O.E., did not want to dictate either what should be taught or how it should be taught. Instead, they supported a range of materials and methods. Thus, for the elementary grades, ESS developed over 50 independent units focused on exploring phenomena encountered in nature and organized for the classroom; SCIS endeavored to provide more selective experiences for children that could lead them to discover specific science concepts; the AAAS sponsored *Science a Process Approach* relied on behaviorist theory to introduce children to a sequence of skills that comprise scientific methods in a particular order (observation before measuring before classifying, etc.); while MINNEMAST, at the U. of Minnesota, developed a combined mathematics and science curriculum for the early grades.

Encouraging diversity in schools, with different content, pedagogy and outcomes was an explicit goal of improving science education. The 1961 AAAS conference report, while urging that all new science curriculum should have "a clear progression in the study of science from grade to grade" and "should stress the spirit of discovery characteristic of science itself" also emphasized that "There should be no single national curriculum in science." The conference participants were insistent that no attempt be made to develop a single program for use in all school systems. The judgment was based partly on philosophical objections to central dictation of curricular planning, and partly on recognition that "alternative choices of subject matter and order of progression might be equally effective . . .no one knows the best order and selection from among all that might be taught; alternative sets of material should be tried out."[22]

But perhaps the greatest difference between then and now is that the materials were produced and used in schools before the introduction of "standards" and the now ubiquitous high-stakes tests.[23] The nation has moved from benchmarks, guidelines and frameworks (the original "standards" of this movement) published by professional organizations and a few states, to detailed state education department documents that include long lists of facts to learn or nebulous platitudes about science, to accommodate evaluation through multiple-choice tests. This framework limits options for curriculum and professional development.

Conclusion

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. Forty years ago, was probably the high point of this effort, 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.[24] Many of the individual programs no longer exist; they are out of date or they did not survive in the competitive world of textbook adoption.

But what has survived, and 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 US classrooms. And we need to emphasize that high-stakes, multiple-choice tests in science will stifle implementation of inquiry in the classroom.

We need to incorporate these successes into our vision for the future and consistently emphasize that although 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. A century ago, John Dewey argued that inquiry is important for education in a democracy. The work begun almost half a century ago demonstrated that active science education can be part of school; it can be assessed; and it can be implemented on a national scale to lead to a more scientifically literate society that, in turn, will strengthen our democracy.

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[1] Presented at *Science Education for a Thriving Democracy*, a one-day symposium at the Museum of science celebrating TERC's 40th anniversary, November 18, 2005.

[2] I appreciate critical comments provided on an earlier draft of this paper by Dennis Bartels, Brenda Engel and Emily Romney.

[3] A report on October 13, 2005 by the National Academies, *Rising Above the Storm: Energizing and Employing America for a Brighter Economic Future,* released by the NAS Committee on Prospering in the Global Economy of the 21st Century makes the argument for more and better science education on purely economic grounds (as the committee's title implies.) Its proposals for K-12 science education focus almost exclusively on the "brightest" students and the most advanced

courses in order to keep the US competitive in a global economy (http://www.nap.edu/books/0309100399/html). Contrast this with the AAAS Report quoted in the announcement for this conference, which includes “America’s ability to create a truly just society” as the first reason for supporting science education. *Science For All Americans* (AAAS, 1989, p. xiii)

[4] For a parallel view of issues discussed in this lecture, *see Reflecting on Sputnik: Linking the Past, Present, And Future Of Educational Reform* papers presented at a symposium hosted by the center for Science, Mathematics and Engineering Education, National Academy of Sciences, October 4, 1997. http://www.nas.edu/sputnik/agenda.htm, retrieved December 4, 2006.

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

[6] I was ignorant of much of the history of education and I had no idea that I had actually joined a staff that included a strong contingent that recognized the historical significance of the progressive education movement in the US.

[7] See, Buderi, R. (1996) *The Invention that Changed the World: How a Small group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*. New York: Simon and Schuster.

[8] 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.

[9] 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.”

[10] J. Zacharias, Research scholars and curriculum development, *ESI Quarterly Report*, Summer Fall 1965, p. 101-104, adapted from an address presented at the General English meeting of the Modern Language Association, New York, NY, 12/29/64.

[11] “This approach to secondary school physics has been taken with the conviction that it is appropriate both for students who expect to continue in physics or other sciences, and for students who will have no further formal contact with physics.” Physical Science Study Committee, (1965) Physics: *Teacher’s Resource Book and Guide, part 1, 2nd Edition.* D. C. Heath, p. vii. Other secondary school projects make similar claims in their introductions. All stress that the courses focus on what we call inquiry today, on having students observe, experiment, and draw conclusions from evidence. They also frequently emphasize that these process skills can be applied beyond the subject, and that students’ realization of the broader applicability of inquiry skills may be the most important outcomes for students taking the course.
It can be argued that the courses were “to hard’ in the sense that most of these texts for one-year courses included more material than could usually be covered in a single academic year. Many PSSC teachers covered only a fraction of the entire text. But the same criticism can be leveled at many school texts. The *intention* was to produce material for average students.

[12] TERC, (1976) *Ten Year Progress Report*,” unpublished document, Cambridge, MA: Technical Education Research Centers, p. 1

[13] AAAS (1961) op. cit.

[14] IPS Team, (1967) *Intermediate Physical Science*, Englewood Cliffs, NJ: Prentice-Hall, p. v.

[15] *Ibid, p. 221.*

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[16] Karplus, R. and H. D. Thier, (1967) *A New Look at Elementary School Science.* Chicago, IL: Rand McNally & Co., p. 4.

[17] I don't remember *any* science in my elementary school in Binghamton, NY in the 1940's nor do most others of my generation with whom I've talked. Mike Atkin writes, "While I remember lessons in history, geography, arithmetic, spelling and art, I recall little that was labeled 'science' during my attendance at a public elementary school in Brooklyn, New York in the 1930s." (Atkin, J. M. and Black, P. (2003) *Inside Science Education Reform*, New York, NY: Teachers College Press.)

[18] This charge is true for a majority of projects from the second major round of NSF funded elementary science curricula, the so-called Triad Projects from the 1980's. Many of them were ill conceived, underfunded and involved difficult collaborations between publishers and developers (a requirement for funding).

[19] Another arena where the science materials of the 1960's are actively used is the science museum and science center community. ESS is particularly is well represented there. Science centers around the world have Light Tables, Pendulums, Colored Shadows, Attribute and Pattern Blocks, and Spinning Tables, all ESS units, as well as less obvious derivatives of other ESS units. Also, several scientists and teachers from ESS, most notably Frank Oppenheimer and Philip Morrison, became associated with science center activities.

[20] The striking difference between the "golden age" of science education in the 1960, with its "faith in the social role of education" as well as faith in the validity and usefulness of scientific knowledge and current social views is the subject of Rudolf, J. L. (2002) *Scientists in the Classroom,* New York: Palgrove Press.

[21] Eisenhower's response to concerns about sputnik was not to ask for massive military build up but to increase federal support for education, including strict statutory prohibitions of federal direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution. He also supported a five-fold increase in the NSF budget for educational activities. Eisenhower's support for education in that crisis is discussed in Goldstein, pp. 170-171.

[22] AAAS (1961) op. cit.

[23] High-stakes tests certainly existed ever since the Chinese invented the system for admission to the administrative class some 2,000 year ago. In the 1950's, there were high stakes tests for male college students of my generation; high scores were required to retain a college deferment from the Army during the Korean War. But the *name* didn't exist, nor were they a common requirement for acquiring a high school diploma.

[24] See, for example, Lockhard, J. D. (1967) *Report of the International Clearing House on Science and Mathematics Curricular Developments*, College Park, Md., International Clearinghouse on Science and Mathematics Curricular Developments. The annual reports, published from 1963 until the 1970's, each describe dozens of active science curriculum projects in the United States, some sponsored by local systems or state departments and many supported by NSF. The projects include science for non-science majors, translations of materials into Spanish and programs specifically developed to serve "disadvantaged" students.