LESSONS FROM THE NEW SCIENCE CURRICULUM OF THE 1950s AND 1960s

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The development of the "new science curriculum" began in 1956 with a grant from the newly formed National Science Foundation (NSF) to Jerold Zacharias at the Massachusetts Institute of Technology. He was asked to write a "real science" physics curriculum for high school students. By the end of the 1960s, curricula in earth sciences, physical science, biology, chemistry, and engineering concepts were developed at various universities and scientific institutes.[1] Although they were an NSF-sponsored, discipline-wide effort to improve science instruction, each curriculum was developed independently with significant differences at the conceptual, developmental, and planning stages.[2] By the mid-1970s, after spending $117 million in direct costs and an estimated three times that much in indirect costs (Elmore, 1993), the adoption rates by school districts of these materials had peaked, and the momentum for developing additional curricula was largely gone. What was the context of this major reform effort? How were the curricula developed? What strategies were employed for implementation? What were the outcomes? What lessons can be drawn from that experience that would help inform national standards setting efforts today?

THE POLITICAL AND EDUCATIONAL CONTEXT OF SCIENCE REFORM

Until the 1950s, school curriculum had traditionally been set by individual school systems in response to the perceived needs of local communities. The

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federal government played little role in the setting of curriculum standards in science. At the same time, states had little capacity to create comprehensive curriculum materials on their own. School administrators relied on publishers to develop textbooks that set the curriculum. Science courses provided information on new technology (as opposed to scientific inquiry itself), and such technological marvels as electrical appliances, internal combustion engines, energy, space travel, and telephones became the content focus of much of science instruction. Teachers of traditional science courses used technological application, with bits and pieces of interesting, but unconnected information being loosely structured into general science courses, to teach. In schools, the science curriculum was established by criteria as diverse as student or teacher interest, popular topics featured in the magazines and newspapers, life problems for which scientific information might prove helpful, college requirements, legal requirements for health and safety, as well as the available textbooks and standardized test questions (Hurd, 1969). There was little conceptual unity, and no conceptual bridge between units or the scientific disciplines.

By the end of World War II, a need developed for more and better scientifically and technically trained workers. The increased pace of scientific discovery and advancement was such that much of the content that high school students were learning was already outdated or irrelevant. University scientists were concerned that entering college students were ill-prepared for college science courses because their high school science preparation lacked rigor or training in scientific inquiry. The scientists' concern was that college-bound students be provided an accurate and relevant science background through rigorous science high school courses.

At the same time, the Soviet Union's significant scientific and technological achievements provided the spark for a national discussion about the woeful state of American education, especially in mathematics and science, and prompted the establishment of the National Science Foundation in 1950. By 1954, summer institutes to upgrade scientific knowledge for high school teachers were established, and the first federal grant to develop a new science curriculum was awarded in 1956. The urgency to reform the curriculum was heightened by the successful launch of *Sputnik I* in 1957.

The widespread political urgency for action generated by the Cold War produced consensus that science and math education (along with foreign language) reform should receive top priority. The focus of attention on science and mathematics meant that those courses gained status at the school level and overshadowed courses in the humanities and vocational education. National policymakers agreed on two broad strategies: "to have more science instruction at all levels, and to have a different kind of science instruction at all levels, but especially in the upper grades and beyond" (Jackson, 1983, p. 157).

PLANNING STAGE

In the late 1950s, the NSF had decided that the task of curriculum development be undertaken at the national level by the top scientific institutes instead of by local educators or commercial publishers.[3] Specialists in each scientific discipline would determine the content for each curriculum; it would be drawn from the respective scientific disciplines and represent as faithfully as possible the core knowledge of the scientific disciplines themselves. Inquiry and discovery of scientific principles through laboratory and fieldwork was to replace textbook-based information acquisition. Conflicts were thus primarily technical ones, based on specialized approaches that were unique to each discipline. The fact that each curriculum was designed independently with little interaction among the teams meant that there was little intentional integration or coordination among the disciplines. Current popular technological topics were to remain outside the new courses.

> The authors of the new science curricula prefer to develop courses around the inquiry processes and the conceptual structure of a discipline because these attributes of science are more stable. Technological and industrial applications of scientific principles are topics the teacher might bring to the course when it is advantageous to do so. These applications should be timely and local to be of educational value. While a part of the teacher's repertoire of supplementary reading for the student, they are unsuitable as a structured component of a textbook or course of study. (Hurd, 1969, p. 23)

In general, little attention was given to general educational purposes (the development and exercise of citizenship, the transmission of culture, the improvement of everyday life), science literacy (the role of science in everyday life), or individual student interests and curiosity that might be developed with exploration of technology (spaceships, computers, medicines, materials—the industrial uses of science). Nor was attention given to the content of science courses that non-college-bound students might want or need to take.[4]

SYSTEMIC RELATIONSHIPS

Because the project developers were teachers or scientists affiliated with research universities and scientific institutes, the skills and content necessary to succeed in university science courses provided the framework for the curricula being developed for high school students (Hurd, 1969). On the other hand, because the courses focused strictly on high school curricula, there was a weak relationship between what was being developed at that level, and the science curriculum being taught in elementary and junior high schools. In addition, the curricula were discipline based, so the relationship with other researchers within the subdiscipline was strong.

Although the disciplinary relationships were strong, the linkages to the educational establishment were weak. The limited involvement of high school science educators, science teacher associations, textbook publishers, school administrators, and teacher trainers in the planning stage was a deliberate result of a general dissatisfaction with the way curriculum had been designed in the past (Elmore, 1993), as well as a lack of confidence in the ability of scientists to develop appropriate curriculum. No deliberate effort was made to involve schools of education in the curriculum development or to train preservice teachers in the new curriculum. Issues such as restructuring the school day, the conventional ways that schools operate, or the ongoing training of new school staff were also not a major part of any project's goals.

OVERALL CURRICULAR GOALS AND OBJECTIVES

The primary goal of each NSF-sponsored project was to develop a rigorous curriculum embodied in the units developed at the institutes. The belief was that challenging and up-to-date curriculum, in the hands of teachers, would drive the science education reform; if a teachable curriculum was developed, teachers would teach it. The role of teachers themselves in the development depended on the project. Each project developed its own network of teacher training institutes and its own cadre of teacher trainers. The Physical Science Study Committee (PSSC) invited science teachers to summer workshops to assess the teachability of the materials that had been developed and to pilot the initial materials. In the Biological Sciences Curriculum Study (BSCS), project-nominated science teachers were involved from the beginning with piloting the lessons, designing the instructional units, and evaluating and revising the products. Whether or not teachers were involved in the development of the curriculum, the initial content and instructional approach was determined by the scientists. Doing science was what scientists and students were expected to do, and educators were given the role of transmission. There is no evidence that educators contested the scientist's "definite views of the division of labor between teachers and academic scientists" (Elmore, 1993, p. 23).

Recalling the political climate of the Cold War, the projects were to develop curriculum that would prepare students for college science and potential careers in science. The objectives were to update the content, increase the rigor of the courses, offer more courses, and introduce students to the process of science as actually performed by scientists. This required the reformers to identify what constituted the essential content of each subject area, to develop lessons that used open-ended "discovery method" instructional strategies and extensive use of laboratory experiments and field studies, and to provide an experience for students that was sufficiently interesting and engaging so as to encourage them to pursue further courses in college (Atkin, 1983).

The content would be introduced sequentially, with more simple ideas introduced earlier, and more complex concepts reserved for the end of the course. Each unit would be connected to prior knowledge and skills introduced in earlier units. High school courses would be recast to make science classes more like science laboratories, where students would use the concepts, structure, and operations essential to that field to make discoveries, not simply to report and confirm results.

> Competence in learning is not limited to being able to answer questions from an assignment or to work the problems in the laboratory. A student is expected to know more than an answer; this might include the restricted meaning of the topic, its modification for different contexts, or its expression in quantitative terms. To know something is to have insight into its meaning in terms of the laws, theories, or conceptual schemes of science. It is in this way what is learned becomes useful for thinking and problem solving. Another way of stating [it is this]: does he see the relevance of the concepts, principles, and inquiries constituting the discipline? Has he developed an intuitive capacity allowing him to go beyond the subject matter described as the course? Are his powers of reasoning those that characterize the science he is studying? (Hurd, 1969, p. 32)

DELIBERATIONS

THE ROLE OF THE FEDERAL GOVERNMENT IN DEFINING CURRICULUM

The National Science Foundation was concerned about perceptions of federal influence on curriculum usurping the traditional local authority, so multiple reform projects were sponsored in each discipline area by different development teams. Teams were not allowed to develop material that would be in direct competition with commercial publishers, but how their work would be disseminated was not clear. Development work was done by researchers; in most cases, practitioners provided little input in the curriculum development.[5]

In general, according to Hurd (1969), the various development groups operated under the following assumptions:

1. Content standards must organize the content into a sequence of topics that will promise achievement of course objectives. One consideration is the vertical structure of K-12, and the other is based on the concepts and inquiry processes peculiar to a specific science course. Concepts selected for teaching should be authentic and viable in terms of a specific scientific discipline like physics. Whether the concepts meet the personal and social needs of the students, or are popular with students and teachers, is not the first consideration.
2. Meaningful inquiry in science requires the student to participate in the kinds of inquiries characteristic of the scientific enterprise, such as discovery and investigation.
3. Content of the greatest value will provide the most explanations and have the widest generalizing power. This involves understanding the grand principles, the unifying ideas, and the abstract attributes of science (e.g., chemical bonding and organic evolution).
4. Teaching methods are not generalizable beyond the context of the discipline they represent.
5. A relatively few significant concepts, taught in depth and in context until the student has some intuitive feeling for the topic, is preferable to subject matter "coverage."
6. Each curriculum item should be coordinated with a complete course package, tested and ready for classroom use (including text, lab manual, teacher's guide, tests, films, lab equipment, and lab experiments).
7. The course must not be overly sophisticated or too abstract for the typical high school student, but should be sufficiently challenging and stretching for all students.[6]
8. Content should be designed with a career orientation.

Units were piloted in schools by practitioners who were nominated for their extensive knowledge of and experience in teaching the subject matter. Because the participants were grouped around traditional fields of study, and the concern was to improve preparation for college-bound students, discussions focused on issues within the disciplinary context rather than on larger policy issues such as access, system-wide impact, and school-wide participation.

GOAL AND/OR STANDARD SETTING

To a great extent, the content was predefined by the content and skill prerequisites of the college courses into which the students would be channeled. Students would develop the interest and skills necessary to become professional scientists in the future on the basis of success with actual scientific inquiry, rather than a potpourri of unrelated, but personally interesting, science tasks or experiments. Topics were limited to those that contributed to a student's understanding of the conceptual structure of the discipline.

The process for setting standards generally followed the well-established guidelines for conducting scientific research, with an advisory or steering committee of research scientists in the lead. As experimental curriculum was developed, it was field tested, evaluated, and revised by a cadre of teachers. Some have criticized the minimal involvement of school practitioners at the development stage, but the nature of the curriculum development precluded more widespread use of teachers and other practitioners (Elmore, 1993).

The sequential order of units was critical to each of the projects. Units were presented in order of both increasing content and skills complexity to maximize use of the limited time allocation to science. Courses were designed around units that taught the information and the skills needed to understand the discipline and its dynamic nature, mainly through experiment and independent discovery. Concepts were also evaluated for appropriate introduction at various grade levels. Because of the need for a lengthy introduction, some concepts required introduction at the junior high school level. The more advanced courses depended on prior knowledge and skills, and focused on the development of skills in theory building and testing, not specific answers. Consequently, teachers had to be very comfortable with ambiguous or unanticipated results, and knowledgeable within the subject area.

The deliberate move away from the traditional texts and courses of study, at least initially, and toward a laboratory and field-experiment-based curriculum was based on the conviction that new instructional strategies needed to be employed in addition to the new content. The developers dismissed traditional science texts and lecture style instruction. The development teams worked to shift instruction away from information dispensing to theory building, from data collection to data analysis, from lecture to experimentation. The vast amount of content inherent in each discipline, and its dynamic nature, raised questions about what material should be covered, and whether to survey the field as was done in the past, or to organize more in-depth units to facilitate concept attainment; in the end, the latter was chosen.

SCIENCE EDUCATION IN THE LARGER SCHOOL CONTEXT

The disaggregation of science into unrelated subdisciplinary knowledge and skills meant that high school students would have little assistance in integrating various disciplines and understanding core science concepts and processes as they applied across the disciplines. The projects shied away from new disciplinary alignments or subject areas, such as ecology and biophysics. The emphasis on "pure" science also de-emphasized technology and day-to-day applications, which were generally of more interest to students.

Acquisition of skills and knowledge for daily living was considered a study of technology, not science. Because scientific rigor and preparation was the overall goal, there was little interest in making the new courses part of a general educational scheme, and little connection between the content and any other subject areas, save mathematics. In addition, the science-based emphasis precluded the discussion of significant social questions related to the role of science in society, such as problems of resource exploitation and nuclear weapons proliferation.

Although the courses were all designed for widespread use regardless of ability level, some (e.g., PSSC and Chemical Education Material) required students to have a strong mathematics background. Debate centered around whether the new models were too difficult for average or lower ability learn- ers, or whether they were in fact more appropriate, because they depended less on the rote learning and prior experiences necessary for traditional courses. Nevertheless, because the courses were perceived to be for college-bound students, there was a self-selection process among students (Jackson, 1983). As the broader policy focus shifted in the mid-1960s away from academic excellence toward greater equity and attention to disadvantaged students, there was concern that not all had equal access to and opportunity for high-level science instruction.

OUTCOMES

If the goal of the projects was the development of high-quality materials, the projects were a success. Courses were well designed to teach scientific inquiry at a high level. However, measured against the standard of different science instruction, the results were dismal. Each new curriculum, a significant departure from the traditional curriculum, struggled for widespread acceptance. Initially, over half of the school districts nationwide used at least one federally sponsored project, and 40% used more than one. However, only the Introductory Physical Science (IPS) program, the least demanding of the new curricula, reported adoption by as many as 25% of secondary schools, in at least one class. The rest had adoption rates of less than 15% (Jackson, 1983).[7] In their effort to maintain the quality and integrity of scientific inquiry, the projects may have distanced themselves from wider dissemination and adoption as curriculum standards of instructional practice, which was so much a part of the effort of each project. Such a shift would require large numbers of science laboratory opportunities for teachers to practice science themselves. Despite an initial surge of interest by teachers in the materials, few classes used them as designed; instead, other than the content, length, and difficulty of class, little had changed (Jackson, 1983).

Measured by the standard of "more students taking science," the results were also disappointing. Because the materials were offered as alternatives to the traditional curriculum, not their replacement, courses using them often were taught in addition to the regular, text-driven courses. Fewer students took classes based on the new curriculum. The new science classes began to be seen as "elitist" and too difficult, and not attractive to students.[8] Placing emphasis on college-bound students may have made the science courses even less attractive to the 70% of students who did not intend to go to college, and for college-bound students not interested in a science-based major. Nationally, the number of science classes actually peaked in the early 1970s. Fewer students than ever even took basic science classes. There was a sense that the curriculum reforms in science had left out significant numbers of students, especially those who came to be known as "at risk." The National Assessment of Educational Progress data on science achievement showed a general decline in science knowledge, except for biology (Atkin, 1983).

Perhaps the most lasting effect of the new curricula has been on the traditional textbooks being used in science instruction today. Much of the revised content and shifts in emphasis to laboratory work that were part of the new curriculum became part of the revisions of standard texts and state curriculum frameworks over time (Jackson, 1983). Although each of the projects stressed the need for more inquiry-based teaching strategies, they were not given the charge to develop materials in competition with commercial publishers. As ongoing development and staff training ended with the end of the federal funding, those same publishers incorporated the factual content of the projects and the emphasis on laboratory work into their own textbooks.

FACTORS LIMITING IMPLEMENTATION

Three factors seem to have limited wider and more lasting adoption. First, little consideration was given to how the radically different instructional practices of each project would be taught to teachers in the field. The curriculum was developed within a scientific network that had little connection to the normal curriculum and staff development processes. In fact, the new curriculum hoped to replace the content and pedagogy that they had developed. They overestimated the effect of curriculum reform on teaching practice (Elmore, 1993). They did not have the resources nor had they built sufficient support within the professional educational establishment to train all subject-matter teachers in the processes that needed to accompany the concepts. Although the teachers who piloted the materials were given extensive in-service training, as the materials gained wider dissemination, more teachers began using the materials without a thorough understanding of the changes in instructional strategies that were required. Thus the "new" material was still taught in the "old" way by many teachers (Hurd, 1985).

Second, teachers thought that the materials were too difficult for average students. Teachers were not convinced that disadvantaged students would be able to handle the course, and so, often, the new curriculum would be taught alongside a "less demanding" traditional course. Even teachers often found the materials too difficult; they did not have the background or experience as scientists to create classroom conditions approximating the laboratory. The number of science-trained teachers, especially those familiar with the changes in science that occurred after World War II, was never enough to meet the demand; therefore, significant numbers of science teachers had little preparation for teaching science.

Third, the developers failed to account for the structural constraints to changing teacher practice. Many of the materials required longer class periods, changes in classroom and school-wide organization, significant amounts of time to prepare materials, and the construction of new laboratory facilities. The organizational requirements of active discovery learning were too complex to be carried out in the traditional classroom with 1 teacher per 35 students. Equipment that broke down was seldom replaced. Teachers felt more comfortable teaching the way they had been taught, with a textbook.

Insufficient consideration was given to the demands and interests that compete for resources and time within a school. Additional time for science meant that time for other courses would have to be reduced. The inclusion of evolutionary theory and sexual reproduction in biology classes renewed public controversy. Less enthusiastic public attitudes toward science coincided with a drop in science achievement scores in 1974 (Kirst, 1984). The 1970s brought a public cry for back-to-the-basics instruction and competency-based assessment, and the new science curriculum seemed "experimental" and too open-ended. And it was not clear that the new curriculum would produce the high scores on standardized tests, which emerged as the public measure of a school's quality.

CAPACITY BUILDING

Because the goal of the projects was to develop materials, not to train teachers, there was no real strategy to sustain teacher commitment and interest, or to build teacher development in formal professional education organizations. The new curricula included both new content, and a new way of teaching the subject matter. Teachers were now being asked to teach basic concepts without a regular text, to create a scientific environment for their students, and to provide regular, open-ended, laboratory opportunities. The projects required a staff development mechanism to disseminate the materials and train teachers in their use. Projects measured their success by the quality of the materials, not their level of use in the field (Elmore, 1993). For example, summer institutes were usually staffed by scientists instead of teacher trainers. Their purpose was to test and refine the materials, not necessarily to train and encourage teachers in their own development. Even programs that involved teachers more heavily as producers of the curriculum and as summer institute trainers (e.g., BSCS), were not able to capitalize on their newly developed expertise; when the project ended, the network of teachers and scientists working and planning together dissipated.

Ironically, although the curriculum developers were themselves scientists, and the students were being provided opportunities to learn scientifically, teachers themselves had few opportunities to experience and rediscover science as it was being designed. This required the development teams to understand the organization and practice of teaching at the classroom level. Training teachers to teach a curriculum is not the same thing as teaching or learning scientific training. Teachers needed to be able to actually think and behave as scientists. Instead, they were treated as "receivers (and transmitters) of expert knowledge" (Elmore & McLaughlin, 1988, p. 34).

CONCLUSION:
LESSONS FOR FUTURE REFORMERS

In hindsight, the most obvious lesson learned from the experience of the science reformers of the 1950s is to choose standards of success that fit your expertise. The designer knew a lot more about what to teach than they knew about how to teach it. The new science curriculum was one of the first attempts to build a world class set of courses in a disciplinary field. By that standard, the developers were quite successful. But the creation of an accurate and up-to-date curriculum turned out to be far easier to achieve than the goal of having more science and a different kind of science taught (Jackson, 1983). The belief was that if teachers were provided with quality materials, they would be able and willing to use both the new content and the new pedagogy. Although more rigorous courses were developed, the projects did not necessarily result in more science being taught nor more science being learned. The reform of curriculum was more straightforward than the reform of instruction.

Second, it was not the case that teachers were not involved in developing the materials (Elmore, 1993), but rather that quality materials themselves, even with training, are insufficient to transform teacher practice; the stability and persistence of traditional textbook-dependent instruction was underestimated. Thus a lesson learned, really a speculation realized, is that without substantial commitment, support, and participation from the professional (educational) infrastructure (i.e., preservice teacher training, credential requirements), a local network for ongoing discussion, development and training, and structural adjustments in the school, most teachers will continue to depend on textbooks, and classes will be taught in much the same way as before.

A third lesson to be learned is that the target audience for the reform must be clearly defined. The curriculum, designed for college-bound science students, was offered as a universal science reform. Some students clearly have received better science instruction in high school, and the American domination of the Nobel Prize in the sciences is but one indicator of the quality of science instruction for some. But fewer students took science in the end, and the goal of improved scientific literacy for all seemed as distant as ever. The number of trained and qualified teachers is limited. The prior preparation and interests of students vary greatly in high school. National goals for students, and even federal support, does not necessarily persuade students to make the decisions policymakers desire. Because the new curriculum was not mandated for districts, students had opportunities to take less demanding classes, and counselors sorted students into different classes according to their perception of student ability. At the same time, national policy support for the curriculum was superseded by a move away from only college-bound students, and toward other groups of youth. As the policy environment changed over time, support for the new science curriculum waned. More attention was given to back-to-basics instruction, relevance in the curriculum, and meeting the needs of underachieving and minority youth. The interest in science instruction shifted away from simply providing more and better science instruction for college-bound students to an equally important, but unfulfilled, need to expand the base of students who think scientifically (Jackson, 1983). In the end, it does little good to berate the curriculum reformers in retrospect. They made substantial contributions to updating the content of science courses and textbooks still in use today. And they trained a generation of science teacher leaders.

NOTES

1. Programs that were developed include:

The Secondary School Science Project (also known as the Princeton Project; by course title: Time, Space, and Matter), 1962.
The Earth Science Curriculum Project (ESCP), 1962.
Introductory Physical Science (IPS), 1967.
The Biological Sciences Curriculum Study (BSCS), 1959.
Chemical Education Material Study (CHEM), 1959.
Chemical Systems (CBA Chemistry), 1957.
Physical Science Study Committee (PSSC), 1957.
Project Physics, 1964.
Engineering Concepts Curriculum Project (ECCP), 1967.

2. For a more complete comparative analysis of two programs, BSCS and PSSC, see "The Development and Implementation of Large Scale Curriculum Reforms," (Elmore, 1993).

3. Significantly, the reform initiatives came from the National Science Foundation, rather than the U.S. Office of Education (Jackson, 1983).

4. BSCS was explicit in attempting to design a curriculum for average 10th graders (Meyer & Schneider, 1968).

5. The exception was BSCS teams (Elmore, 1993).

6. This assumption was difficult for the curriculum developers to estimate because they were not familiar with all students, but mainly those who went to college and subsequently took science courses.

7. In contrast, one commercially produced standard chemistry text was used in half of the high school chemistry classes.

8. Summer camps and scholarships for gifted science students increased the perception of elitism.

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