



Research Synthesis on the Science Curriculum Projects of the Sixties

Science curriculum development and teacher inservice programs boomed in the 1960s. Numerous new K-12 science programs were constructed with public and private funds while thousands of teachers flocked to college campuses for refresher courses in the sciences and mathematics. In 1959, almost half of the National Science Foundation budget was earmarked for science education: curriculum development and inservice training. In 1963 there were 412 federally-funded inservice institutes with a total enrollment exceeding 21,000 teachers (Science Policy Research Division, 1975). Science education was on a roll.

But times changed. The boom of the 60s is not even a whisper in the 80s. The strong public support of 20 years ago has turned to distrust and apathy toward science and science education (Paul, 1982). "Knowledge of science is rarely considered a basic by the state boards of education and science education is rarely included in state needs statements" (DeRose, Lockard, and Paldy, 1979, p. 32). In a report comparing U.S. education with other countries the National Science Foundation expressed concern that "... more students than ever before are dropping out of science and mathematics courses after the tenth grade" (NSF, 1981, p. 368). Yet initial proposals for NSF's 1983 budget called for the virtual elimination of the Science Education Directorate and its activities—this in the face of declining student interest and enrollments in science and a severe shortage of qualified science teachers.

This research was conducted as part of a larger meta-analysis project initiated at the University of Colorado under NSF grant SED 80-12310, Ronald D. Anderson, Director.

James A. Shymansky is Professor of Science Education, The University of Iowa, Iowa City; William C. Kyle, Jr., is Assistant Professor, Center for Professional Teacher Education, The University of Texas at Arlington; Jennifer M. Alport is with the Department of Biological Sciences, University of Natal, Republic of South Africa.

Considering the gravity of the problems with declining enrollments and teacher shortages, why isn't science education moving in an upswing again? Tight fiscal policies are surely a factor, but there is another reason for the hesitation to support a new round of science education reform: science education's track record. There is a pervasive notion that the last round of curriculum development failed dismally (Rhodes and Young, 1981), or so it would seem. But were the new science programs of the 60s a failure?

We recently completed a quantitative synthesis of research comparing student performance in new science curricula to student performance in traditional science courses as part of a comprehensive synthesis of research in science education. Our synthesis found consistently positive effects derived from students participating in new science curricula. These results are extremely valuable and timely since educators, curriculum coordinators, and supervisors are seriously reassessing the goals, objectives, purposes, and directions for science education. Furthermore, if the public is to be expected to support future improvements in science education, quantitative assessments of past programs' accomplishments and needs are imperative.

Meta-Analysis: A Quantitative Synthesis

The first step in synthesizing the research results on new curriculum effectiveness required that we define new and traditional science curricula. New science curricula were defined as programs that:

- Were developed after 1955
- Emphasized the nature, structure, and processes of science
- Integrated laboratory activities into course discussions
- Emphasized higher cognitive skills and an appreciation and understanding of the nature of science.

Traditional science curricula were defined as courses that:

- Were developed or patterned after a program developed prior to 1955
- Emphasized knowledge of scientific facts, laws, theories, and applications
- Used laboratory activities as verification exercises or secondary applications of concepts previously covered in class.

The quantitative synthesis perspective to research integration known as meta-analysis was used to assess the effects on student performance of new science curricula. Glass (1976, 1978) introduced the term meta-analysis to refer to the process of analyzing the results of a collection of studies on a related topic. Translated literally, meta-analysis is an analysis of analyses. More important, the process is quantitative; it brings the power of statistical procedures to bear on the results of many studies.

Meta-analysis involves calculating a common metric for defined variables within a study. The common metric measures the magnitude of the difference between groups and is referred to as effect size. The effect size is a measure of the performance difference of two groups on a dependent variable (such as general achievement, student attitudes, analytic skills). Effect size is defined as the mean difference between treatment conditions divided by the control group standard deviation:

$$ES = \frac{X \text{ new curriculum} - \bar{X} \text{ traditional course}}{SD \text{ traditional course}}$$

Thus, a positive effect size indicates that students in the new curricula performed better than students in traditional courses while a negative effect size indicates the reverse. An effect size near zero indicates little or no difference in student performance for the selected variable.

We synthesized the results of 105 experimental studies involving more than 45,000 students. We were able to calculate 342 effect sizes on five student performance criteria (achievement, student attitudes, process skills, analytic

skills, and related skills) across 27 different new science curricula. Sample characteristics such as grade level, community type, length of study, student gender, and socioeconomic status, as well as other treatment and study characteristics were also recorded.

General Findings

On a composite basis across all curricula, students in new science curricula outperformed students in traditional science courses by 13 percentile points (equal to a mean effect size of 0.34). The consistent pattern of positive effect size means for such diverse performance criteria clearly establishes the superiority of the new science curricula over traditional science courses in enhancing student cognitive and affective outcomes. Figure 1 shows the relationship between the calculated effect sizes for each performance criterion and the average percentile ranking of students in new science curricula compared to traditional groups.

Achievement

We found that achievement scores of students were effectively raised 14 per-

centile points when they were in classes using a new science curriculum. Moreover, we observed this same increase in achievement scores consistently in elementary, junior high, and high school. Achievement scores were most greatly enhanced for female students (21 percentile points), urban students (29 percentile points), and low and high socioeconomic status students (35 percentile points). Clearly, student achievement was enhanced by the new science curricula. The claim that the new curricula were too soft or not sufficiently content-oriented to maintain adequate levels of achievement in the sciences is not supported by our analysis.

Critics of new science curricula imply that the decline of student scores on college entrance exams and other standardized achievement tests in the early 1970s was the result of the new, process-oriented science curricula. Beyond the fact that it is erroneous to assume a direct cause and effect from what is clearly correlational data, it is interesting to note that no single new science curriculum was ever adopted by more than 25 percent of the school districts in the country. Most new curricula never

made it into the schools. When one considers the low adoption rates and our data showing a clear superiority of students in new science curricula on achievement measures, it is difficult to blame the new science curricula for declines in student achievement.

Attitudes

Following a crisis there is little problem in generating public and private support for a cause. So it was with the launching of Sputnik by the Soviet Union in 1957. Historically, Americans seem to respond with the most vigor when the crisis seems most serious; public attitudes change quickly. But changing student attitudes is far more difficult. Students don't tend to respond to crises that they don't perceive as such. One of the main objectives of the new science curricula was to raise student interest and to enhance student attitudes toward science. Our results suggest that the new science curricula were equally effective in raising student interest and attitudes as they were in raising achievement scores (see Figure 1).

Across all curricula, student attitude scores were 14 percentile points higher for students in new science programs compared to traditional groups. Student attitudes were enhanced 11 percentile points at the elementary level and 17 percentile points at the high school level. Junior high students showed the highest increase in attitudes—22 percentile points above their traditional counterparts. Classes with predominantly female students (greater than 75 percent) showed a 13 percentile point improvement while classes with a mix of student gender showed an even more positive attitudinal change (20 percentile points). Suburban and urban students also tended to have a high increase in attitudes towards science (16 and 24 percentile points respectively).

The only attitudinal data we found to be contrary to the positive trend appeared in classes that were predominantly male (greater than 75 percent) and in rural areas. Predominantly male classes using new curricula were adversely affected by 1 percentile point while students in rural schools were 3 percentile points below their traditional counterparts.

As in the case of the achievement scores, opponents of the new science programs may have been guilty of faulty logic in blaming declines in student



Highlights from Research on Science Projects of the 60s

Research shows that students in "new" science curricula outperformed students in "traditional" courses, regardless of grade level, science discipline, or student/teacher/school characteristics.

Achievement. Achievement scores of students in "new" science courses improved across all grade levels, with female, urban, and low and high socioeconomic status students showing the greatest increases.

Attitudes. "New" science courses enhanced student attitudes toward science, especially at the junior high level, in urban areas, and in classes with a mix of male and female students.

Process, Analytic, and Related Skills. Student performance in process skills, problem solving, and critical thinking was improved by the "new" science. In addition, at the elementary level, student performance improved in the related skill areas of mathematics, reading, social studies, and communication. In high school, the BSCS and PSSC programs seemed most effective in improving students' analytic skills. Across all performance measures studied, though, students in BSCS made the most gains.

interest in science on the adoption of nontraditional programs. Again, our analysis shows consistently high marks for the new programs in enhancing student attitudes toward science.

Process Skills, Analytic Skills, and Related Skills

Process objectives became synonymous with new science curricula over the years. At the same time, perhaps the areas most stressed by new science curriculum developers were problem solving and critical thinking (analytic skills). Student performance in both the process skills and analytic skills was enhanced by participation in new science curricula.

The related skills criteria include the effects of new science curricula on mathematics skills, reading skills, social studies performance, and communication skills (writing and speaking). The promise of enhanced student performance in related skill areas was never advertised loudly by new curriculum proponents, but it could be inferred from much of the early rhetoric that gains in these areas could be achieved. Only three elementary science curricula were studied to any great extent (SCIS, S-APA, and USMES) yielding an effect size mean of 0.33 derived from 43 effect sizes. Based on our analysis, it is probably safe to conclude that student performance in related skill areas at the elementary level was greatly enhanced by the new science curricula. It is interesting to note that many elementary schools have dropped science from their curriculum in order to "return to the basics." Perhaps the trend should be to

include more process-oriented science in order to enhance the development of basic skills.

How Did the High School Curricula Fare?

In the period following Sputnik, more than two dozen well-known science curricula emerged. At the high school level the Physical Science Study Committee (PSSC), the Biological Sciences Curriculum Study (BSCS), and the Chemical Education Materials Study (CHEM Study) were the most well known and widely adopted of the new curricula. According to the research literature, the track record of each of these programs is worth noting.

Across all performance measures studied, BSCS programs were the most effective of the high school curricula. Students in BSCS classes out-scored their traditional course counterparts by 23 percentile points. For PSSC students the margin was 18 percentile points and for CHEM Study students, 5 percentile points. On specific performance measures (for example, achievement), PSSC and BSCS students consistently out-scored traditional students by 19–22 percentile points.

Curiously, student analytic skills seemed to have been equally enhanced in both the BSCS and PSSC programs. Research on PSSC students revealed a 20 percentile point increase over traditional students while the BSCS studies showed an 18 percentile point increase. On a related measure, process skill development, BSCS students showed a 32 percentile point enhancement.

The cumulative record of student performance data is most impressive for

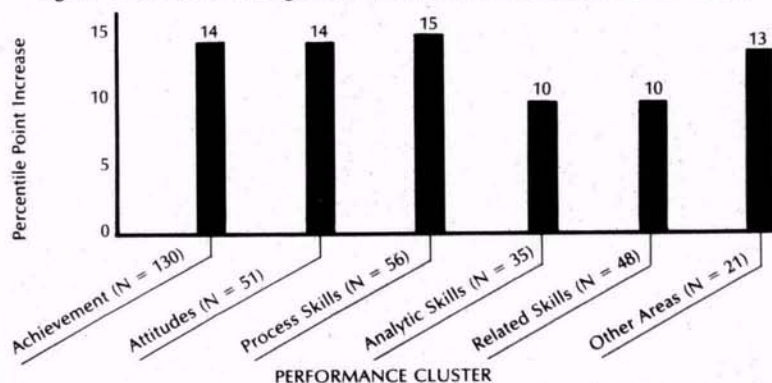
the PSSC and BSCS programs. The results for CHEM study are less impressive but nonetheless positive: 6 percentile points on achievement and 11 percentile points for analytic skills.

A Curriculum Score Board

In analyzing the research literature we were able to identify five distinct student performance criteria: achievement, attitudes, process skill development, analytic skills, and related skills (reading, computational math, social studies, and communication skills). We also subjected each new science curricula encountered in the research literature to a rating in terms of its level of emphasis on inquiry, process skill development, content, individualization, and laboratory skills. Each curriculum was given a score of 1–4 on each characteristic. Some of the results of our analysis for all curricula (K–12) are as follows:

1. BSCS-Blue, MINNEMAST, SCIS, and PSSC were most effective in enhancing student achievement (more than 20 percentile points higher than the control group).
2. BSCS-Blue, BSCS-Yellow, and ESS were most effective in enhancing student perceptions.
3. BSCS-Blue, S-APA, BSCS-Yellow, and SCIS were most effective in enhancing student process skill development.
4. BSCS-Blue and PSSC were most effective in enhancing student analytic skills.
5. USMES was most effective in enhancing student performance in related skills.
6. New curricula rated high in emphasis on inquiry more positively enhanced student achievement, process skills, and related skills.
7. New curricula rated low in emphasis on inquiry more positively enhanced student perceptions and analytic skills.
8. New curricula rated high in emphasis on process skills more positively enhanced student performance in each of the five student performance criteria.
9. New curricula rated low in emphasis on laboratory skills more positively enhanced student attitudes, analytic skills, and related skills.
10. New curricula rated high in degree of individualization more positively enhanced student attitudes, analytic skills, and related skills.

Figure 1. Percentile Changes in Performance Clusters for New Curricula.



11. New curricula rated low in degree of individualization more positively enhanced student attitudes, analytic skills, and related skills.

12. New curricula rated low in emphasis on content more positively enhanced student achievement, perceptions, process skills, and related skills.

13. Student overall performance scores were more positive for mixed student samples (greater than 25 percent males or females in class) than for predominantly female or male samples.

14. Student overall performance was found to be more positive in either urban or suburban schools than for rural environments.

15. Student overall performance was found to be significantly more positive for both high and low socioeconomic student samples than for mid-socioeconomic groups.

Summary

Our findings reveal that the new science curricula had consistently positive effects on student performance regardless of grade level, science discipline, or student/teacher/school characteristics. The overriding message in the results we have presented is that the new science curricula developed in the 1955-1970 period were far more effective in enhancing student performance than critics were willing to give them credit for. However, just as it was popular in the 60s to develop new science courses from scratch to replace traditional programs, so has it become popular in the last five to ten years to discard these programs and return to the basics.

Previous reports such as the three K-12 Status Study reports (Helgeson and others, 1978; Stake and Easley, 1978; Weiss, 1978), the professional reviews of the Status Study reports (NSF, 1980), and the reports of Yager (1980a, 1980b) allude to a crisis in science education. These reports all portray a grim view of the current status of science education, especially in light of the back-to-basics movement. Most people appear to view the basic skills as reading, mathematics, and communication; science is rarely seen as basic by the general population (NSF, 1980). But science is as much a basic as reading, writing, or arithmetic if you consider that it involves (or should involve) all the basic skills within it. If science is taught in a way that brings students in contact with their environment and themselves, it could probably

be successfully argued that science is even more basic than the three Rs!

In recent years science has been left off the list of basic skill areas in schools, much to the dismay of science educators. But that may not be all bad: science isn't a skill to be learned by rote as are rules of reading, punctuation, spelling, addition, subtraction, and on and on. If inclusion on the list of basic skills implies memorization of information, then it is just as well that science is not considered a basic skill. Science can, however, be used to teach basic skills.

Our analysis shows that students like science better when taught as inquiry, without sacrifice in achievement or related basic skills. Junior high students were especially enthused with the new programs. Curricula that stress drill and memorization of science facts are less likely to turn kids on to science and do little to enhance performance in basic skills. Science through at least the eighth grade should focus on generating interest, not on amassing information. Improved skills in both science and related areas are a logical extension of an exciting science experience.

Activities that emphasize higher-level cognitive skills, critical thinking, and problem solving should be incorporated into the existing science curriculum. These activities can be interdisciplinary in focus and/or can integrate science and societal issues. Finally, science educators might also use the push for improved reading, writing, speaking, and mathematical skills to improve instructional techniques in the sciences that would not only help students master these basic areas but also result in more effective teaching/learning of science. This study should lend strong support to such contentions.

We do not suggest a return to the old "new science curricula." Rather, we suggest that the activities and strategies that characterized many of the discarded programs be re-examined and given a second chance. Considering the positive impact on student performance that many of the new science curricula had, perhaps we can't afford not to return to some of these strategies and materials. EL

References

DeRose, J. V.; Lockard, J. D.; and Paldy, L. D. "The Teacher Is the Key: A Report on Three NSF Studies." *The Science Teacher* 46, 4 (1976): 31-37.

Glass, G. V. "Primary, Secondary, and Meta-Analysis of Research." *Educational Researcher* 5 (1976): 3-8.

Glass, G. V. "Integrated Findings: The Meta-Analysis of Research." *Review of Educational Research* 5 (1978): 351-379.

Helgeson, S. L.; Blosser, P. E.; and Howe, R. W. *The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-75*. Vol. 3. *Science Education*. Washington, D.C.: U.S. Government Printing Office, 1978.

Kahl, S., and Harms, N. "Project Synthesis: Purpose, Organization, and Procedures." In *What Research Says to the Science Teacher*. Vol. 3. Edited by N. C. Harms and R. E. Yager. Washington, D.C.: National Science Teachers Association, #471-14776, 1981.

National Science Foundation. *What Are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field*. Washington, D.C.: National Science Foundation, SE 80-9, 1980.

National Science Foundation. "How the U.S. Compares with Other Countries." *Educational Leadership* 38 (February 1981): 368-370.

Paul, R. H. "Are You Out on a Limb?" *Educational Leadership* 39 (January 1982): 260-264.

Rhodes, G. L., and Young, D. B. "Making Curriculum Development Work Again." *Educational Leadership* 38 (May 1981): 627-629.

Rutherford, F. J. "Preface." In *NSF Report SE 80-9, What Are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field*. Washington, D.C.: National Science Foundation, 1980.

Science Policy Research Division. *The National Science Foundation and Precollege Science Education: 1950-1975*. Washington, D.C.: U.S. Government Printing Office, 1975.

Stake, R. E., and Easley, J., Jr. *Case Studies in Science Education*. Washington, D.C.: U.S. Government Printing Office, Stock No. 038-000-00376-3, 1978.

Weiss, I. R. *Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education*. Washington, D.C.: U.S. Government Printing Office, Stock No. 038-000-00364, 1978.

Yager, R. E. *Crisis in Science Education*. Science Education Center Technical Report 21. Iowa City: University of Iowa, 1980a.

Yager, R. E. *Status Study of Graduate Science Education in the United States, 1960-80*. Final Report for National Science Foundation, 79-SP-0698. Iowa City, University of Iowa, 1980b.

Yager, R. E. "Prologue." In *What Research Says to the Science Teacher*. Vol. 3. Edited by N. C. Harms and R. E. Yager. Washington, D.C.: National Science Teachers Association, #471-14776, 1981.

Copyright © 1982 by the Association for Supervision and Curriculum Development. All rights reserved.