

The Engineering Science Talent Pipeline: Early Intervention*

H. KIMMEL

Center for Pre-College Programs, New Jersey Institute of Technology, University Heights, Newark, New Jersey 07102, U.S.A.

The development of future engineers and scientists is enhanced by reaching youngsters at the elementary grade level with a diversity of programs. Students are brought to the university campus for science and computer classes. An outreach program involves graduate students and faculty working with teachers in their elementary classrooms to enhance science instruction, and to improve the teachers' skills and confidence. Resources of other educational agencies are used to strengthen the programs.

THE ISSUE AND ITS IMPLICATIONS

NATIONAL studies [1-3] have concluded that there is a very real crisis in engineering and science education. Our future depends upon the maintenance of a sufficient number of adequately trained engineers and scientists to respond to national and global needs and priorities. These reports have also underscored the critical need to address human shortages in entering scientific and engineering fields, especially minority and women populations. Despite a steady increase in the number of minorities receiving undergraduate degrees in these fields, the problem of under-representation of minorities remain.

Society's increasing dependence on technology, coupled with expected changes in student demographics, will make it increasingly important to utilize all potential human resources to the fullest extent possible, and to concentrate on those groups with historically weak rates of participation in engineering and science. The growing fraction of college students that will be drawn from minority populations implies that programs aimed at increasing the participation of minorities will be an especially important source of new technological talent.

PREVIOUS EFFORTS

Evidence suggests that well-designed intervention programs can assist minority groups in obtaining access to careers in engineering and science [4]. Most efforts since 1972 have focused on intervention during the high school years and have resulted in improved access for minorities in the engineering and scientific fields. Such increases have been

salutary but not nearly enough. Twenty years of involvement in pre-college engineering and science programs [5] has convinced New Jersey Institute of Technology (NJIT) that the greatest success in such efforts should result from interventions in student academic programs going back to the fourth grade or earlier. Indeed, reports confirm that the pool of students from which future engineers and scientists are developed must be expanded by providing students with greater educational opportunities at a younger age [6].

Motivation to study science and math does not come easily to students who have few career role models in those areas, and who attend schools in which the science and math curriculum is inadequate. It is believed that an essential ingredient in the development of future engineers and scientists is exposure to hands-on experience and opportunities for exploration in math and science for elementary age students. Indeed, teaching science by practising science is one of the best techniques to motivate youngsters to learn.

EARLY INTERVENTION STRATEGIES

The development of an engineer or scientist is a long-term, continuous process that should begin with the first grade in school. Intervention must be a sustained effort, but must eventually become institutionalized, that is, made part of the educational system.

In recent years, a major strategy of the Center for Pre-College Program at NJIT has been to develop programs that impact on inner city youngsters early in their school experience. The NJIT programs focus on hands-on science activities and computer experiences. In some instances, elementary students come to campus to use our science laboratories or work in our Pre-College Computer Center. Other activities involve NJIT students and

* Accepted March 20, 1993.

faculty working with teachers in their elementary school classrooms to enhance science instruction, and to improve the teachers' skills and confidence.

A critical area in which NJIT has responded to the needs of Newark elementary schools is in computer education. Three years ago, the district announced its plan to have computer labs in all elementary schools, and a computer curriculum to start at the fourth grade. Due to limitations on resources and other constraints, those plans are not expected to be fulfilled in all Newark elementary schools. One school was given terminals which are not really appropriate for student use. A second school was given micros, but no computer teacher; thus the computers were locked up and unavailable for student use. A third school is considered too small and unable to provide appropriate security for setting up a microcomputer lab. The schools came to us for help. As a result, fourth and fifth grade classes of these schools have participated in computer classes in LOGO conducted in the Pre-College Computer Center at NJIT. The classes provided by NJIT followed the curriculum described by the district for those schools with computers. The youngsters were taught by a NJIT undergraduate student, with assistance from student members of the Society of Black Engineers and minority staff in the computer services department. Thus, the computer classes not only introduced the elementary students to computers, and helped to develop their problem-solving skills, the activity also provided role models for the youngsters, and the opportunity for them to visit a university campus on a regular basis.

The programs focusing on elementary science are designed to make science a priority item in the curriculum of an elementary school, and to increase time devoted to it in the daily schedule, by demonstrating that the elementary science program can be structured to complement and strengthen rather than compete with efforts to build skills expected in other disciplines. The science improvement programs are based on the premise that the study of science provokes abundant high-level motivation in children. Science can be an integral part of the elementary school program. It should be used to integrate, reinforce and enhance the other basic curriculum areas so as to make learning more meaningful for children. Reading, writing, mathematics and science are not mutually exclusive. Science can be a part of mathematics instruction or a language arts experience.

Due to lack of facilities, most science programs in elementary schools are text-centered, read-and-tell programs with little if any hands-on activities. The NJIT efforts expose the youngsters to science classes which involve hands-on experiences. Where possible, the design integrated computational, reading and writing skills into the science materials and activities. In this way, we seek to modify or develop curriculum materials that allow science lessons to help the students achieve the

expected basic skills proficiencies, rather than be left as an addendum to the school curriculum.

The earliest efforts involved the use of a 'teacher corps' of NJIT undergraduates from economically and educationally disadvantaged backgrounds in an engineering science outreach program. This was designed to enrich the science experiences of Newark fifth and sixth graders and encourage them to aspire to careers in engineering and science [7]. The NJIT students taught basic scientific and engineering concepts, conducted problem-solving sessions, and directed a related project that emphasized direct student involvement. They also served as models of success in overcoming obstacles to obtain an undergraduate degree, as they shared their academic and career interests and accomplishments. The program offered the elementary youngsters insight into technical fields not normally available in the elementary curriculum, provided real role models, and made them aware of technical career opportunities. Benefits were also derived by the undergraduates who received a sense of accomplishment and satisfaction in being able to repay the community, in part, for the opportunities and education they had received.

The 'teacher corps' concept was modified to involve minority graduate students, under the supervision of NJIT faculty, to supplement the current science classes and focus on those topics that are included in the science curriculum guides in the Newark school district. Working with the elementary school teachers, activities are chosen which use the process skills within the content of the science curriculum.

This effort has been well received in the elementary schools and appears to have had a positive impact on science learning. Representative of the letters received from the elementary youngsters was the following:

'I wish you can bring Nancy back because she's a great science teacher. I learned so much since she came. I learned how to make a projector and weight by using a nut, and all different kind of stuff. So please continue the science program and send Nancy to Quitman St School where she belong.'

In addition to the graduate students, we have NJIT faculty working with elementary school teachers in the classroom to help them design and implement hands-on activities which integrate computational, reading and writing skills into their science lessons. Again the focus is to make science a priority item in the curriculum of the elementary school, and increase the amount of time devoted to it in the daily schedule. In addition, additional training is provided for the teachers in the content and pedagogical areas on a regular basis during the school year.

Teacher training must be an integral part of efforts to improve elementary science instruction. The NETS Project (Network of Excellence in the Teaching of Science) is a statewide effort dedicated to improving the quality and extent of science instruction in urban elementary schools. Under

NETS, NJIT has been working in the Newark school district to motivate a large number of elementary teachers to devote more classroom time to science, and which effectively provides them with the experiences, knowledge and materials to use in their classrooms. Emphasis is on those activities which complement the school's adopted curriculum and for which materials and supplies are inexpensive and readily available in the home or supermarket. The computational and writing skills to be integrated within the activities are those identified by Newark educators. Also, these teachers work cooperatively with the NJIT faculty in the design and implementation of the science activities. In this way, the teachers are becoming proficient and comfortable in the teaching of science, so that in future years, they will teach science utilizing the hands-on approach. In addition, Newark has increased its support for the teaching of science in the elementary grades, placing a greater emphasis on the importance of science in the curriculum. Ultimately, as science becomes a regular part of the elementary curriculum, NJIT faculty will be needed only as an available resource.

Appropriate collaborations with other organizations, e.g., museums, can lead to successful interventions and greatly enhance the learning experiences of elementary grade students. For instance, the recent establishment of New Jersey of the Liberty Science Center will provide many opportunities for university- and museum-type collaborations for improvement of education in the urban centers.

Currently, NJIT is collaborating with the New Jersey Marine Sciences Consortium (NJMSC) on a project to enhance the science learning of Newark elementary grade youngsters through exposure to marine science concepts [8]. Involving students and their teachers, the project includes field experiences at the salt marshes and ocean beaches of New Jersey, and in-school programs which provide advance instruction directly related to the field experiences. NJMSC marine education specialists provide these components of the project. NJIT faculty and graduate students handle the classroom-based programs, which integrate the marine

science experiences into the elementary science curriculum by providing the students with interdisciplinary hands-on activities. These hands-on activities are built around basic science concepts, as illustrated in the marine environment.

Perhaps the most important aspect of the early intervention strategy is for the university to be responsive to the needs of the local elementary schools. Answering a call for help can result in the development of a beneficial long-term relationship between the university and the school. As a result of a letter to the Institute's President, for the past several years, NJIT faculty have helped a Newark elementary school teacher develop hands-on activities for her fourth, fifth and sixth grade 'basic skills classes', which augments the curriculum being developed by the teacher. The students receive the immediate benefits from this effort and the teacher now provides these science activities without the presence of the university faculty in the classroom.

CONCLUSION

This paper aims to encourage urban-based colleges and universities to reach out to local elementary schools in order to inspire and encourage youngsters to envision higher education and careers in the engineering and scientific fields as achievable goals. Both the university and its population, and the elementary schools and its students and teachers can benefit greatly when the university can be responsive to the needs of the schools.

Most importantly, long-term commitments are needed at the elementary grade levels. We are probably looking at something that may take 10 to 15 years to see a change because of the deep problems that exist in elementary science teaching. Many approaches are possible for the task of improving the teaching of elementary science; but most probably, they should involve in-service training of the teachers with follow-up support for the teachers in the classroom, all within the framework of the existing curriculum within the school or school district.

REFERENCES

1. B. M. Vetter and E. Babco, *Professional Women and Minorities: A Manpower Data Resource Service*, 6th edn. Commission on Professions in Science and Technology, Washington, DC (1986).
2. Office of Technology Assessment (OTA), *Demographic Trends and the Scientific and Engineering Work Force*, US Government Printing Office, Washington, DC (1985).
3. M. J. Lane, The current status of women and minorities in engineering and society, *Engng. Ed.*, **78**, 750-755 (1988).
4. H. E. Fischer, Pre-college engineering programs for minorities: which approach is more effective?, *Engng. Ed.*, **75**, 115-117 (1984).
5. H. Kimmel, N. Martino and R. Tomkins, An approach to increasing the representation of minorities in engineering and science, *Engng. Ed.*, **79**, 186-189 (1988).
6. S. Stinson, Engineering education: early intervention to balance the scales, *NSBE J.*, **3**, 40-48 (1987).
7. H. Kimmel, An engineering-science outreach effort for minority elementary grade students, *Engng. Ed.*, **78**, 84-85 (1987).

8. J. Ramadas, L. Novemsky and H. Kimmel, The Jersey coast explorers: a marine science program for inner city schools, *Proceedings of the Conference on Pre-College Education of Minorities in Science and Engineering*, pp. 245–247. Newark, NJ (1988).

Howard Kimmel is Professor of Chemistry and Director of the Center for Pre-College Programs at New Jersey Institute of Technology. As Director of the Center, he is responsible for almost 30 programs that service over 3000 elementary and secondary grade level students and teachers. Programs are designed to increase access to scientific and engineering fields among traditionally underrepresented population; to improve the teaching of science and mathematics in secondary and elementary schools; and to improve and enrich science and mathematics curricula. Dr Kimmel has led the movement to involve universities in pre-college programs at the elementary grade levels. These programs involve collaborations of schools, the university and the corporate sector. Dr Kimmel has received state and national recognition for his efforts, including the prestigious Vincent Bendix Minorities in Engineering Award presented annually by the American Society for Engineering Education.