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New technologies have generated increased and varied application of scientifically based materials in the world of work, thereby increasing the importance of science and math knowledge and skills for workers. For many students, science and math are intimidating subjects. Low achieving and average students tend to shy away from such

courses as they represent unfamiliar and difficult concepts. Stereotypic images and expectations, lack of self-confidence, and failure to perceive relevance are some of the reasons that females are so greatly underrepresented in courses in mathematics, science, and technology (Fear-Fenn and Kapostasy 1992).

To be competitive in the work force, however, these barriers must be overcome as the demand for workers with relevant science knowledge and problem-solving skills increases. This ERIC DIGEST addresses National Education Goal 3, which states in part that students will demonstrate competence in challenging subject matter including mathematics and science. This DIGEST highlights exemplary curricula and model programs and describes strategies for integrating science, math, and vocational education.

Helping students learn more about science and technology and become more skilled at problem solving and analysis has been the goal of recent educational efforts. Many of these initiatives involve the integration of academic subjects with vocational education in a combined curriculum and instructional delivery. In this way, students have the opportunity to apply their academic knowledge to specific occupational tasks and to solving problems typically encountered in business and technical fields. Pritz (1989) notes that science provides the foundations for creative thinking and cognitive development, which engenders a depth of understanding that allows for generalizability and transfer across real world tasks. This emphasis on science-vocational education integration is consonant with the recommendation of the Secretary's Commission on Achieving Necessary Skills (1991) that skills in systems and technology, necessary for all workers, be taught in their "natural home in science courses" (p. 22).

EXEMPLARY PROGRAMS

The National Science Foundation (NSF) recently funded several experimental integration projects. One involved the collaborative efforts of the Illinois Board of Education, Northern Illinois University's Department of Technology, five industrial partners, and five northern Illinois schools (PHYS-MA-TECH 1992). The goal of the project was to attract average high school students who typically avoid physics by providing an integrated math, physics, and technology curriculum offered in a nontraditional learning environment through team teaching and innovative delivery models.

To initiate the project, teams of math, physics, and technology teachers at each high school analyzed existing course content for common concepts and skills, which were used to develop the integrated curriculum. Because good content and courses already existed, it was not necessary to create an entirely new curriculum for a given course. Integrated instructional delivery was essential to the project's success, and integrated teaching was made possible by nontraditional scheduling. The PHYS-MA-TECH curriculum consists of 45 instructional activities, 6-13 from each of the 5 high schools. The real-world context for the science and math content is apparent in some of the

topics: laser burglar alarm, exercise machines, ultrasound, smoke alarm, programmable home thermostat, and bar coding.

Also funded by NSF, the Technology/Science/Mathematics Integration Project conducted in Virginia middle schools (LaPorte and Sanders 1993) was based on the rationale that science and math instruction tends to be strong in theory but weak in practice, technology education the reverse. The project focused on application of science and math principles to real-world problems, with technological problem solving the common thread among the three disciplines.

A materials science and technology program resulted from a collaboration among Battelle Pacific Northwest Laboratories, Central Washington University, Northwest Regional Educational Lab, and Richland (Washington) School District (MATERIALS TECHNOLOGY 1990). This program uses integrated and cooperative learning techniques to link both the scientific understanding of materials and their composition to the technological application of materials in the world of work.

In Tennessee, a course integrating science and agricultural education (Ricketts 1991) was created to enable college-bound students to participate in an agriculture course that would count toward their college credit requirements. This course has become a model for integrating vocational and academic education and has been popular with students. Course enrollment figures for 1991-1992 (the second year of the program) remained high.

INTEGRATION STRATEGIES

These and other successful programs that integrate curricula rely on the collaborative efforts of teachers across disciplines. Because team teaching is a requirement of most integrated courses, programs attempting this mode of instruction devote time and effort to training teachers to integrate learning concepts. The MATERIALS TECHNOLOGY (1990) program, for example, has the following requirements:

--Staff must have the opportunity to work with materials in industry or laboratory settings before they begin teaching the course.

--Both academic and vocational teachers should deliver this course together as students learn both theory and practice simultaneously.

--The course must use the tools of the trade to the greatest extent possible.

--The use of community experts is highly desirable as is the support of a business/industry advisory committee that can help locate resources, materials, equipment, and internship opportunities for students and staff alike.

--Staff must use cooperative learning techniques.

Experience in cooperative and collaborative team teaching is also important for teachers as they learn the content and instructional mode of other disciplines. As teachers become more knowledgeable about each other and other subject areas, their respect for others increases as does their confidence in the benefits of integration. The importance of this to the success of integration is apparent from Daugherty and Wicklein's (1993) study, which found that the math and science teachers surveyed generally did not understand the scope and purpose of technology education or how to integrate the disciplines.

Integrative efforts require open communication between science/math and nonscience teachers. In creating interventions for special needs learners that link science and vocational education, for example, it is imperative that teachers practice interprofessional collaboration to address the varied learning styles, characteristics, and needs of special students; strategies for teaching difficult science concepts; and the sharing of laboratory facilities and equipment (Greenan and Tucker 1990).

Some of the benefits teachers realize as a result of team teaching integrated science, math, and vocational courses are as follows:

--Each discipline becomes stronger on its own merit.

--There is increased mutual respect among teachers of various disciplines.

--Teachers improve their teaching skills and expand their repertoire of strategies and techniques.

--Enthusiasm and motivation for teaching increase.

The Center for Occupational Research and Development (CORD) has been a leader in integrated curriculum development. Based on CORD's experience in developing Principles of Technology, Applied Physics, Applied Mathematics, and Applied Biology and Chemistry, Hull (1990) recommends (1) using a systems approach instead of teaching a series of discrete topics; (2) integrating math with problem solving; and (3) integrating biology and chemistry in the context of personal, work-related, and societal issues.

CONCLUSION

April 1993 is the 10th anniversary of A NATION AT RISK (National Commission on Excellence in Education 1983), which reported the "steady decline in science achievement scores of U.S. 17-year-olds as measured by national assessments of science in 1969, 1973, and 1977" (p. 9). It appears that little progress has been made in the 10 years since A NATION AT RISK presented the challenge for educational reform. Results of the International Assessment of Educational Progress (Science), as reported in USA TODAY ("Riskline" 1993) show U.S. students at the bottom of the list of participating countries:

- Korea 78%
- Taiwan 76%
- Switzerland 74%
- Hungary 73%
- Soviet Union 71%
- Slovenia 70%

- Italy 70%
- Israel 70%
- Canada 69%
- France 69%
- Scotland 68%
- Spain 68%
- UNITED STATES 67%
- Ireland 63%
- Jordan 57

%Statistics such as these highlight the importance of upgrading the science and math skills of U.S. students. Integrating science, math, and vocational education is one way to accomplish this, offering many students who have excluded science and math from their vocational programs the opportunity to succeed in these disciplines. Programs such as those described here can offer guidance to educators who see the need for and the benefit of moving in the direction of integration.

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