Preparing a Skilled Work Force in Engineering, Science and Technology – A Tri-fold Approach

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Abstract — *This paper describes a project to develop and implement a career cluster program for the Research, Development and Technical Services career major. Specifically, the Engineering, Science and Technology - Tech-Prep Grant, sponsored by the New Jersey Department of Education, has three main goals: preparing a skilled workforce that meets industry and educational standards in the fields of engineering, science and technology; establishing a consortium to improve training opportunities for students and teachers, and improving and expanding articulation between the secondary and post-secondary providers of education and training. The approach of the project is tri-fold, in that it partners the expertise of teachers and educators from secondary schools, educators and technical researchers from higher education, and engineers, researchers and managers from technical industries. The methodology of the project is to develop a local consortium of comprehensive schools, county vocational schools, two-year colleges, a research university, and the technical industry base to provide leadership in enhancing the pre-engineering curriculum to ensure that New Jersey's youth are adequately prepared for entrance into two-year and four-year engineering, science and technology degree programs. The ultimate goal is to motivate and prepare students for careers in engineering, science and technology.*

Index Terms — *Articulation, careers, curriculum, pre-engineering, engineering, science, technology.*

INTRODUCTION

New Jersey has a population of over eight million people and a very diverse technological industrial base, spanning such fields as telecommunications, pharmaceuticals and health care. It ranks seventh in the US in technology jobs, which is the third largest employment category in the state, exceeded only by financial services and education [1]. To help fulfill an economic need for qualified people seeking career opportunities in the state's research and development (R&D) industry, a program was established to develop a pool of academically prepared, technically sophisticated youth. Sponsored by a grant from the New Jersey Department of Education that began in September 1998, the purpose of the Engineering, Science and Technology (EST) - Tech-Prep program is to develop a local consortium of comprehensive schools, county vocational schools, two-year colleges, four-year colleges and research universities, and the R&D industrial base to ensure that New Jersey's youth are adequately prepared for entrance into two-year and four-year engineering, science and technology degree programs. The ultimate goal is to motivate and prepare students for careers in engineering, science and technology.

While there have been several tech-prep programs [2-3], in order to be successful, these programs must insert career and technical education into the center of all the programs [4], deliver material to its partners in a timely fashion, address the education of its teachers, and provide a seamless path from the secondary school through college. This program is a multifaceted tech-prep program, oriented to more than just creating introductory courses to engineering and science. The approach of the project is tri-fold, in that it partners the expertise of teachers and educators from secondary schools, educators and technical researchers from higher education, and engineers, researchers and managers from technical industries.

Based on a five-year development cycle, this program developed career clusters [5] for over ten disciplines within engineering, science and technology. As shown in Table 1, focus is on one of these major career clusters per year. During each year, various activities were directed at these specific disciplines, including linkages between the educational and industrial partners, project based learning modules, professional development and articulation agreements [6].

PROJECT PARTICIPANTS

Participating schools were required to have an approved engineering/pre-engineering Classification of Instructional Program (CIP) code, which is part of the New Jersey Department of Education classification of high school programs. The two major participants in this grant are Bergen County Academy and New Jersey Institute of Technology (NJIT). Bergen County Academy incorporates The Academy for the Advancement of Science and Technology and The Academy for Engineering and Design Technologies, which are public magnet schools for science and technology located in Bergen County, New Jersey. NJIT is one of only three designated public research universities in the state of New Jersey and ranks among the leading engineering/technology research universities in the United States.

The ten additional secondary schools that have participated in this grant include: Camden County Technical School, Cape May County Vocational School, Gloucester County Institute of Technology, Middlesex County Vocational & Technical High School, Monmouth County Vocational School, Morris County School of Technology, Newark Public Schools, Red Bank Regional High School, Salem County Vocational Technical School, and Union County Vocational Technical Schools. Because these graduates can articulate to a two-year community college program, five community colleges were also included as educational partners. These schools included Essex County College, County College of Morris, Gloucester County College, Salem County College, and Union County College. The level of involvement of the individual schools and community colleges varied from year to year, and was primarily dependent upon the correlation of their programs with the career cluster focus of a particular year.

Coordination with industry is one of the key factors in developing successful educational programs. In addition to the educational partners, there were over twenty industrial partners, representing many of the major industrial corporations within New Jersey, such as Lucent Technologies, Allied Signal Corporation and Becton Dickinson & Company. Another part of the industrial linkage were representatives from the Research & Development Council of New Jersey, which is a non-profit association representing over 50 major New Jersey companies. The purpose of this organization is to create a strong, healthy environment for the continued growth of R&D within the state of New Jersey. Its responsibility under the grant includes a mentoring program for representatives of the educational partners and cultivating internship sites for students at the representative high schools.

SKILL SET FOUNDATION

NJIT faculty developed an extensive skill set list, to be used as a foundation for the study of engineering, science and technology. These competencies/skill levels were identified in the areas of mathematics, science, engineering principles, design, technology and communications (written and oral), and were considered prerequisite competencies for the individual career clusters. In addition, success both in a university setting as well as in the job market requires competencies in areas such as oral and written communication and interpersonal relationships.

Table 2 illustrates skill set categories and subcategories that were developed during each of the five years of the program. While the first year represented the development of specific career clusters for Mechanical Engineering and Physics, the development of these skills sets have proven to be general in nature. Although many of the categories were repeated and additional subcategories were included, there were only six new skill set categories added during years two through five. [6] For example, during the second year when the Chemical Engineering, Chemistry and Environmental Science career cluster was developed, most of the skill set categories crossed multi-disciplines within engineering, science and technology and only chemistry was added. A complete listing of all the skill set categories, subcategories and corresponding New Jersey Core Content Curriculum Standards is available through Bergen Academy on the Tech-Prep Website. (http://www.bergen.org/EST)

A curriculum project template, developed by Bergen Academy faculty, facilitated establishing a relationship between the skill sets and the New Jersey Core Curriculum Content Standards. [7] The core curriculum content standards were an attempt by the state to define the meaning of "Thorough" in the context of the 1875 New Jersey State constitution that guarantees that students would be educated within a Thorough and Efficient, i.e., "T&E", system of free public schools. These standards ensure that all children receive a "T&E" education despite the fact that in New Jersey there are approximately 600 independent school districts that exercise considerable local control over curriculum. These standards describe what all students should know and be able to do upon completion of a thirteen-year public education.

PROJECT BASED LEARNING

A project development format was created, which coordinated the skill set list and facilitated consistency during successive years. NJIT developed several “seed projects”, and the other educational partners used this format to continuously develop

additional problem sets. Partner schools were given the skill set, and the creation of a particular project involved marking the specific skills that were covered. Although a particular project may cover only a small fraction of the entire skill set list, eventually, all the skill sets were linked to one or more projects as more projects became available from the educational partners. During the first year, a total of 14 problem-based, interdisciplinary projects were established, that were delivered to approximately 45 of a total of 120 participating students, at 3 demonstration sites. With the addition of new projects and improved availability, the number of participating students increased to over 1100 with 100 percent access. Upon completion, the individual projects were placed on the Tech-Prep website for use by all the educational partners. Links are typically provided from the project page to an instructor page, a student page, and additional websites with related tutorials, similar projects, and existing products. The activities in the projects were also related to the New Jersey Core Curriculum Content Standards.

Other methods to disseminate project-based learning that have been utilized during this grant consist of interactive teaching modules, instructional CD-ROMs, curriculum guides and various other resources that were posted on the Tech-Prep website, including the West Point Bridge Designer Project. [8] In addition, the integration of Project Lead the Way (PLTW) [9] programs into the high school curricula was a major factor in increasing the project-based learning modules for the high school educational partners. By the end of year four, 30 New Jersey schools, including eight of the Tech-Prep partners, used this pre-engineering program. [10] Its purpose is to increase the quantity and quality of engineers and engineering technologists graduating from the nation's educational system. PLTW has a four-year sequence of courses that combines with traditional mathematics and science courses in high schools. During year five NJIT became the PLTW training site for New Jersey.

STUDENT COURSE EVALUATIONS

Table III shows the results of student course evaluations of seven classroom project units taken in grades 9-11. An independent third party evaluator took the surveys and provided summaries as part of an annual grant assessment report. [11] The questionnaires contained ten statements regarding the student experience within the particular unit. The statements were gauged to illicit responses indicating student opinions as to whether the units were motivating, informative, challenging, well-designed, and provided them with skills that would help them in college or their careers. The student responses were based on the rating system shown, i.e., ranging from one to five, indicating *disagree* to *strongly agree* respectively. All of the ten evaluations received a general overall rating of at least three to five. However, it should be noted that there is a definite trend toward acceptance of the more academically oriented project units with increasing grade level. The ninth grade students overwhelmingly preferred the Battlebots to the other two project units they took. The tenth grade students were evenly divided between their four courses, giving both Battlebots and Principles of Engineering a five rating. The eleventh grade students preferred their two more academic courses, i.e., Principles of Engineering, and Engineering and Design Development to the Computer Integrated Manufacturing project unit. Careful planning and reassessment of ninth grade project units is indicated as a worthwhile future activity to avoid early negative influences.

TECH PREP WEBSITE

The main vehicle used to communicate and disseminate various information on projects and events throughout the consortium is the Tech-Prep website that was developed by Bergen Academy. Figure 1 shows a portion of this webpage, i.e., http://www.bergen.org/EST/, which contains nine main areas, including: goals and objectives; skills sets; contact information; project information; resources; articulation agreements; career awareness; internship information; summary of meetings.

EDUCATIONAL STAFF PROFESSIONAL DEVELOPMENT

Educational staff professional development is an important part of this grant. Originally it was though that a series of seminars for the participating teachers at the educational partners would provide a structure for professional development. However, due to time restrictions placed on many the teachers during the academic year, it was decided that distance learning training material would be more readily acceptable to these participating teachers. Consequently, participating NJIT faculty developed a series of seven videotaped modules during years two through five. Each module focused on presenting career information and creating projects to be disseminated by the teacher. Effective staff development fosters and reinforces project replication by all EST partners.

Other staff development opportunities ranged from onsite workshops to individualized technical assistance services and online resources. The posting of projects, curriculum recommendations, resources and materials, supply lists, textbooks, software and equipment on the EST website enabled teachers to both develop and more effectively implement project-based instruction. The PLTW model was also used to facilitate staff development for both teachers and counselors.

STUDENT FOCUS EVENTS

Each year high school students from partner schools were invited as guests to a series local education/industry career fairs at NJIT to gain an introduction to careers in EST. The last two career fairs had over 120 companies each, and students were able to observe the interviewing process, as well as gather information on the career potential in EST. Career based information and links to NJIT's Division of Career Development Services are also posted on the EST web page.

Internship and mentoring programs were fostered between the educational and industrial partners, especially in research and development (R&D). The R&D Council, an industrial partner, sponsored 15 internships at its member corporations. Monmouth County's High Technology High School, had a student mentorship program that placed a senior in a science/technology firm part-time for one semester. The students work on a research or design project selected jointly by the mentor, faculty project consultant and the student, and a final presentation on this effort is required. The County College of Morris, arranged visits between its students and members of SCORE, which is a national network of volunteer retired business executives and professionals. Members meet with the students, both in person and over the Internet, to both discuss careers in the research and development areas as well as arrange worksite visits.

Career development of underrepresented minorities was addressed through a series of student-oriented events geared to women in engineering. NJIT's pre-college center offers a year-round program called FEMME (Females in Engineering: Methods, Motivation and Experience), which encourages post ninth-graders to enroll in advanced mathematics and science courses, and consider engineering and related careers. The current level of interest among these groups demonstrates the success of these programs, i.e., thirty-seven percent of the participating students are female, and twenty-nine percent represent minority groups.

ARTICULATION AGREEMENTS WITH EDUCATIONAL PARTNERS

The development and/or revision of articulation agreements between the community colleges and the participating high schools, community colleges and NJIT and between the participating high schools and NJIT are an integral part of this program. NJIT has worked with the educational partners, to review such items as curriculum, student subject matter performance levels, the degree to which students demonstrate an ability to work on projects and on teams, teacher qualifications and teacher methodologies.

NJIT has negotiated two agreements with the community college educational partners – Union County College and Raritan Valley Community College – for their Associate Degree in Science. NJIT also has an agreement with the Academy for Engineering and Design Technologies (AEDT), enabling students to have advanced standing (sophomore year status) upon their enrollment in NJIT. The advanced standing is dependent upon completion of an articulated curriculum (the model for this project) which was developed by the faculties of NJIT and AEDT, students graduating from AEDT with a GPA of B or better, and success on NJIT's placement tests. Twelve articulations are under development reflecting the above combination of PLTW curriculum models and EST curriculum-based projects

A student tracking system, which facilitates the tracking of student achievement after program completion, has been developed. Continuity within this system is maintained through the inclusion of competency-related items in all follow-up instruments. Also, a number of the participating schools maintain active and detailed alumni connections, and these will be used in the future to determine the success of this program.

CONCLUSION

The Engineering, Science and Technology Tech-Prep Project was designed to develop and implement a career cluster program for the Research, Development and Technical Services career major. The program, through the use of project based curricula, articulation agreements, and coordinated expectations for new workers with industrial partners, defined educational standards required for successful postsecondary study and entry into career positions in engineering, science and technology.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the NJIT faculty who developed the individual specialized programs: Professors James Grow, Ken Chin, Norman Loney, Thomas Olenik, Dorairaja Raghu, Stanley Riesman, Reginald Tomkins, Special Lecturers Maura Deek and Geraldine Milano, and Dr. Dennis Siginer, Dean of Engineering, Wichita State University, who was the Co-principal Investigator during the first two years of this grant.

The authors also wish to acknowledge the support provided by the Messrs. Jason Sanservino and Mark Tronicke, grant coordinators for Bergen Academies for years 2-4 and 5 respectively.

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FIGURES AND TABLES

FIGURE. 1
THE MAIN TECH-PREP GRANT WEBSITE.

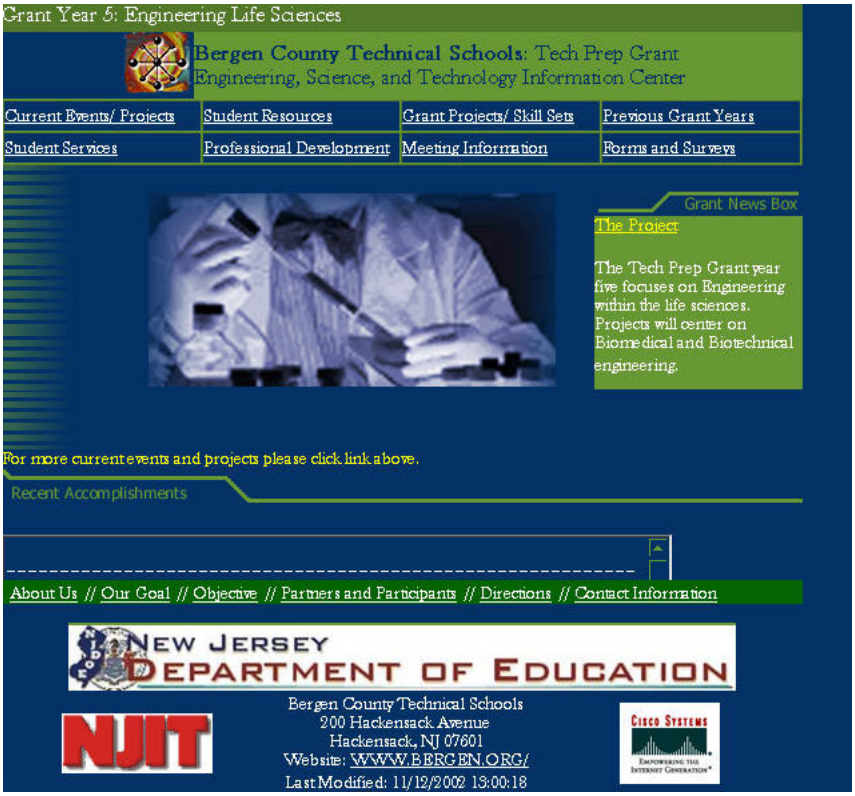

TABLE I
SEQUENCE FOR CAREER CLUSTERS

Year	Career Clusters
1	Mechanical engineering, physics and engineering technology
2	Chemical engineering, chemistry, environmental science and technology
3	Electrical and computer engineering, material science and technology
4	Civil and environmental engineering, material science and technology
5	Engineering life sciences, including biomedical and biotechnical engineering and technology

TABLE II
SKILL SET CATEGORIES AND SUBCATEGORIES BY YEAR

Year	Main Category	Subcategory
1	Math	Algebra
		Graphing
		Geometry
		Trigonometry
		Calculus (optional)
	Physics	Time and motion relations
		Simple electric circuits
	Dynamics	Newton's laws
	Computer knowledge	Windows environment
		File management
		Use of the internet
	Problem solving skills	Defining the problem to be solved
		Collecting and sorting information
		Ability to estimate or predict a solution
		Working within given constraints, recognizing those constraints

		Drawing conclusions
		Results that meet the objective
	Communication skills	Reading
		Speaking
		Writing
	Team skills/project management/personal	Time management
		Personal
		Communication
2	Chemistry	Stoichiometry
		Classical principles: mass and energy conservation
		Classical laws: Dalton, Charles, Boyle
		Systems of measurement
		Units conversion
		Quantitative representations
3	Research/information skills	Questioning - independent discovery of issues and problems when looking at a topic
		Coherent structuring and organization of information
		Synthesizing - reconstruction/combining of information to make sound/original decisions
		Reporting – translation of findings into a persuasive, instructive, or effective arguments/facts
	General technology skills	Ability to assess usefulness/application of basic information technology
		Basic understanding of the relationship between career choices and specific information technologies
		Knowledge of the critical importance of continuous learning, and information technology skills development
	Ethical skills	Understanding of important issues of a technology-based society
		Recognition of ownership, security, and privacy issues
4	Chemistry	Organic chemistry
		Industrial products
		Waste generation
	Environmental studies	Earth sciences
		Biology and microbiology
		Field observations and sampling
	Computer knowledge	Word processors
		Spreadsheets
		Scientific application software packages, e.g., MathCad
	Personal skills	Knowledge of various cultures and diversity in the community
5	Biology	Cellular and molecular biology
		Genetics
	Physics	Geometrical and physical optics
		Optical instruments
	Research/information skills	Writing – how to keep a journal
		Library references
	Problem solving skills	Translating the problem statement into mathematical equations
		Knowing sources of information

TABLE III
STUDENT COURSE EVALUATIONS

Course	Grade	Overall Rating Disagree				Strongly Agree
		1	2	3	4	5
Introduction to Engineering Design I	9					
Autodesk Inventor	9					
Autodesk Inventor	10					
Battlebots	9					
Battlebots	10					
Introduction to Engineering II	10					
Principles of Engineering	10					
Principles of Engineering	11					
Engineering and Design Development	11					
Computer Integrated Manufacturing	11					