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America's polytechnics : bridging a skills gap for learning and applying technological change.

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AMERICA'S POLYTECHNICS:
BRIDGING A SKILLS GAP FOR LEARNING
AND
APPLYING TECHNOLOGICAL CHANGE

A Dissertation Presented

by

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ABSTRACT

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America's economic success will continue to depend in large part on the innovative skills of a technically-educated workforce. Needed change to improve college preparatory skill levels in the public secondary schools will not be forthcoming by the year 2000. The problem is determining how to educate the high school graduates that have been traditionally attracted to the polytechnics (programs in architecture, engineering, and technology) and to prepare them for the changing needs of the 21st Century workforce. Based on a review of the literature and academic and professional society studies, current skill development of students at the polytechnics and the anticipated changes in the technological workforce are reviewed. The skills gap caused by decreasing preparatory skills of high school students and the expected skill development at the polytechnics are examined. This study develops a number of academic bridges and other suggestions to compensate for the learning skills gap at the polytechnics. Chapters include: The Polytechnics; The Technical Workforce and Workplace; The Polytechnic Student; Academic Bridges; and Future Bridges.

TABLE OF CONTENTS

INTRODUCTION

America's polytechnics (those schools offering programs in architecture, engineering, and technology) are at a critical point in their development. In addition to responding to frequent changes in technology, the economy, the professions, accreditors and government policy makers, polytechnics are now attempting to address two new issues that have the potential of dramatically changing the foundation and possibly the existence of undergraduate education in engineering and technology as we know it today.

As reported by the National Science Foundation in their 1993 Annual Report, interest by high school students in studying science and technology has declined from 8% to 5% nationally since the early 1980s (National Science Board [NSB], 1993). This decrease has caused a number of polytechnics to recruit and admit students into programs who in the past would not have been high on the list of preferred candidates. A second issue is the continuing decline of academic preparation and learning skills of those admitted into the programs. Each of these issues are effecting the polytechnic's ability to attract qualified students who can develop the prerequisite problem solving skills for the challenges of tomorrow's technological sophisticated environments and economies.

This dissertation describes how America's polytechnics are responding and adapting to these new problems of declining interest and academic preparation. To provide the context for this dissertation, ongoing changes within the technical workforce that affect the polytechnics' ability to attract, educate, and prepare future graduates are examined. Current educational strategies that have been developed and implemented at America's polytechnics to bridge an expanding gap between learning skills and the changing technological applications in the workforce are also reviewed.

Since the early twentieth century, rapid technological change and world events have combined to create a need for an educated and technically-trained work force in the United States as the country sought to achieve its political and economic goals. This need became critical as the country assumed a new role as world leader after World War II. Polytechnic education, a chief beneficiary of the relationship between business and government, evolved and flourished, especially during the early 1960s. During this period, the polytechnics were able to attract qualified faculty from academe and industry, recruit meritorious students, acquire needed resources from government and industry, and create a demand and acceptance for their graduates in business, education and government. However, by the 1970s a number of societal changes had begun to affect the quality of K-12 education and the interest of high school graduates in continuing with education in the disciplines of science, engineering and technology. Educators and the polytechnics specifically did not begin to recognize this problem until the 1980s.

Since the publication of A Nation at Risk in 1983 by the National Commission on Excellence in Education, little has changed to improve the college preparatory skills of students at the secondary school level. Reports published by the American Society for Engineering Education titled Changing America: The New Face of Science and Engineering (1988) and by the Commission on Professionals in Science and Technology titled By the Year 2000: Myths and Facts (1991) state that fewer and less prepared students are being admitted into America's universities to study science, engineering and technology -- disciplines that are traditionally the backbone of America's economic prosperity.

> It is hard not to conclude that too much undergraduate education is little more than secondary school material - warmed over and re-offered at much higher expense, but not at corresponding higher levels of effectiveness (Wingspread Group, 1993, p. 7).

Despite the numerous studies and calls for action by leaders from business, government and education to address the crises in learning during this past decade, improvements will not occur until well after the year 2000 because politicians and educators alike will not change (NSB, 1993).

As a result of diminished college preparatory skills of students studying in the technical disciplines, a gap between the learning skills received at the secondary school system and those required at the polytechnics has evolved. This gap has frustrated students, faculty and employers who have been working in concert to prepare future graduates and employees to learn the increasingly sophisticated technologies needed in the technical workforce. America's economic success will continue to depend in large part on the innovative skills of a technically-educated workforce.

As a practicing architect and part-time lecturer who decided to make a career change in the late 1970s to full-time teaching, I have observed and experienced a number of changes in the entering students' preparation for post-secondary course work in science, engineering and a number of professional specialties like architecture. Part of the growing concern in higher education is that many more students are graduating from high schools with passing or above average grades, but clearly with less understanding of science and mathematics in particular. Also, over the last decade my own experience suggests that many high school graduates also lack the basic reading, writing and comprehension skills to think through word problems. Despite this, many of the students who are still attracted to polytechnic education are willing to learn and to apply their new skills to practical problems. This motivation and work ethic exhibited by students has inspired me as an educator to find ways to help them overcome their lack of preparation.

As a member and officer of a number of professional societies related to engineering and architecture, I have observed many changes in the practice of architecture and engineering that require polytechnic graduates to perform and learn at quicker paces in their place of employment. As an educator and academic administrator, I have also observed faculty at today's polytechnic universities who have difficulty keeping up with the information explosion within their disciplines. As a result, they have not been able to integrate these new technologies or techniques into the curriculum in a timely way. Adding to my frustration is the fact that fewer high school students are motivated to study in the technical disciplines today.

As a board member of a private technical high school in Boston, my greatest concern is that, as a society, we are graduating future generations of less-than-prepared students to learn and succeed in today's technical world. As a society we owe these students an adequate educational preparation. As educators in higher education, we need to find methods to build bridges between a student's current level of learning and future educational and career objectives. As a nation that must compete in a world economy, we have no other choice. The impetus for beginning this dissertation was and continues to be my personal desire to find these bridges that will allow tomorrow's high school graduates to develop the learning skills necessary to help achieve their personal goals at the polytechnics and beyond.

America's polytechnic schools represent approximately twenty-six percent (26%) of those students being educated in the undergraduate disciplines of engineering and technology (Engineering Workforce Commission, 1994 and American Society for Engineering Education, 1994). During the 1980s, the polytechnics first introduced remedial courses into the curriculum to address the needs of incoming students who were inadequately prepared for studies in technology. As the problems in secondary schools increased, the polytechnics introduced numerous non-degree, pre-technology and pre-engineering programs beyond high school to prepare students for their undergraduate degree programs. Additional academic support systems were also introduced. These included learning centers, placement examinations, and special summer programs to assist the growing number of entering undergraduates with poor college preparatory skills. In some cases, faculty have also revamped their course content and pedagogy to accommodate diminished learning skills and preparation. Despite these efforts, student attrition remains high. While the college preparatory skills continue to diminish, the external pressures from industry and accreditation agencies to add more material to the curriculum have increased. It is this combination of stresses that caused a learning skills gap at the polytechnics and that still impedes their ability to educate quality graduates for America's economic needs in technology.

The problem is determining how to educate high school graduates who have been traditionally attracted to the polytechnics and how to prepare them for the workforce given their current level of skill development.

This study examines the specific learning skills deficiencies exhibited by entering first year students at the polytechnics and, specifically, answers the following questions: What are the learning skills needed for undergraduate study at the polytechnics? What are the skills that students will most likely attain as a result of their secondary school educational experience within the next decade? What are the projected educational needs for a quality and flexible technical workforce in America? Why have previous efforts by the polytechnics to accommodate the poorer entry skills of students failed? What is the projected impact on the existing pedagogical and curricular structures at the polytechnics? To answer the above questions, this study was organized around five chapters.

Chapter One - The Polytechnics describes the twentieth century influences that have shaped the undergraduate degree programs that prepare the majority of America's high skilled technical work force today. Included in the discussion is a description of the polytechnics' educational objectives, curricular structures and pedagogy. Educational enhancements that were developed with industry, such as internships or cooperative work experiences, program accreditation, admissions requirements, and graduate placements are also discussed in this chapter. Additionally, the chapter reviews the many influences on the polytechnics including those from the professional and business communities, educational and scientific communities, learning models, and program accreditors. The chapter concludes with a review of current internal and external issues affecting the learning skills of entering students at the polytechnics.

Chapter Two - The Technical Workforce examines the turbulent environment in which the technical workforce is required to compete. The focus of this chapter is to characterize the learning, knowledge, and application skills expected of graduates of the polytechnics to maintain a flexible technical workforce for America's economy. There is a detailed discussion of the technical workforce and the competencies that organizations are seeking when they hire individuals to help them compete in a global economy. Shifts in the quality and capability of the current technical workforce and the projected educational and learning skills needs of this workforce for the next two decades are discussed.

Also reviewed in this chapter are the findings affecting undergraduate education from industry and government. We will examine Workforce 2000 (Johnston and Packer, 1987), America's Choice: high skills or low wages (National Center on Education and the Economy, 1990), "The Alden Seminars" (University of Massachusetts at Boston and the Association of Independent Colleges and Universities in Massachusetts), and Made in America (Dertouzos, Lester and Solour, 1989).

Since industry continues to be a primary source of technical faculty for the polytechnics, an examination of changes in work design is also included in this chapter. Shifts from the turn-of-the-century "Taylor Methods (Taylor, 1967)" of simplistic work tasks to complex problem-solving processes are discussed. With increasing management emphasis on total quality and a strategy to empower people to make more local decisions, techniques like re-engineering and Total Quality Management (TQM) are reviewed. The evolving interest of industry to utilize team approaches to work tasks and to require technically-educated workers to have a broader spectrum of skills are also reviewed.

The competencies that the professional disciplines believe will be needed for tomorrow's technical workforce are discussed in relation to the learning and knowledge skills that the polytechnics will need to incorporate into the curriculum. Other issues related to preparing future graduates with the aptitude to specialize in more than one area of their professional career, adapt to change brought about by technology and global competition, and participate as an effective team member in multi-disciplined technical and non-technical environments are discussed. The need for lifelong learning skills to regularly continue with one's own education on the job as well as in academe are examined based on the evolving expectations for the future workforce by employers. These professional competencies and knowledge skills are then summarized in the chapter to better understand what bridges are needed at the polytechnics based on the academic preparation of entering students.

Chapter Three - The Polytechnic Student describes the gap between the way polytechnic education had been traditionally taught in the 1960s and 70s and the pedagogical approaches developed since the middle 1980s to address declining academic preparation of high school graduates for college studies. The impact of declining preparation on the expected learning and knowledge skills of entering students is studied in relationship to existing curricular structure, pedagogy, accreditation requirements, and student retention activities. Reasons for the decline in academic preparation at the high school level are considered, and their impact on the polytechnic's ability to educate future engineers and technologists is identified.

In summarizing the current incoming polytechnic student skills profile, an examination of demographic, economic, educational and societal changes affecting the academic preparation of future students is conducted. To better understand this current student profile, previous "bench-marks" for admitting students to the polytechnics over the last two decades by educators are compared to the applications of today.

The decline in academic preparation in the overall public educational system (K-12) in this nation parallels the depth of change at the secondary school level. This change has directly affected learning at the polytechnics. Changing social values and the ability of local government to support public education have contributed to this decline in public education. Demographic shifts and the inability of diverse population groups to advance themselves educationally and economically in the existing social structure have created much turmoil. These issues and others are examined in the chapter to seek better insight into the skill development needs of students arriving at the polytechnic.

In addition, the chapter examines the impact of less teachers at the secondary school level who have been educated in the related disciplines of engineering, technology or science. Former Massachusetts' Secretary of Education Piedad Robertson stated at a symposium in November, 1991 on professional education in Boston, that only 40% of secondary school teachers in science had received formal education in the basic sciences and only 60% of math teachers in mathematics. For the polytechnics, this means that there are also fewer teachers in the secondary schools who are prepared to encourage new students to study technical disciplines.

The impact of declining college preparatory skills is also discussed in relation to the anticipated changes at the polytechnics including new program accreditation standards, a de-emphasis on the role of specialization at the undergraduate level, the anticipated shortage of undergraduate faculty with teaching and professional experience, and the growing interest by industry for graduates to participate in continuing education throughout the graduate's career.

Chapter Four - Academic Bridges examines a number of educational strategies and innovations that have been developed and implemented by the polytechnics to address diminishing college preparatory skills. Included in the chapter is a review of programs and activities designed to improve the recruitment of non-traditional and better qualified students, alter faculty teaching styles to enhance student learning, change attitudes at the polytechnics to provide intrusive advising and services to support students in the learning environment, and adapt curricular structure and course content to reflect changes in the technical professions. Other initiatives such as the federally-funded National Science Foundation's Tech-Prep partnerships with comprehensive and vocational schools and articulation agreements with four and two-year colleges are also examined.

Chapter Five- Future Bridges summarizes the learning gaps from the preceding chapters and the approaches being used to bridge the learning skills gap at the polytechnics. Among the conclusions discussed are the revolution in work design articulated in Chapter Two, the expected next generation of polytechnic students developed from Chapters One and Three, and the evolutionary changes in the present experimental learning and teaching paradigms discussed in Chapter Four .

This chapter suggests how the polytechnics, during a period of declining societal preparedness and interest in engineering and technology education, can compensate for the skills gap in learning and enable students to learn and apply technology.

Recommendations for future bridges and additional study aimed at developing future educators who are now being attracted to the polytechnics, restructuring faculty allegiances to better serve undergraduate education, defining new expectations and joint efforts with the professions, accreditors, and the polytechnics to provide continuous learning for the technical workforce are discussed.

I would like to conclude this introduction with a few personal reflections on the impact that this dissertation process has had on my learning and understanding of polytechnic education and as a part-time student working full time in higher education.

When I began to think about a topic for the dissertation there were a number of issues that my colleagues and I were struggling with related to student retention and recruitment. How we eventually resolved these issues would determine the competitiveness of our schools to survive in technical education. At first, we believed that these problems were specifically related to our own institutions and, therefore, within our power to resolve these issues ourselves. We thought that by better educating ourselves as leaders on the campus we could then provide the necessary direction and training to others in the organization to create change. After attending a number of seminars and conferences we began to implement a number of programs designed to improve recruitment activities, provide better student services, and improve the content of our curriculum. The emphasis on our approach was to improve the current systems in the academic environment through better management techniques and training.

When I first approached my advisor, Dr. Schuman, with my topic on management in education, he asked me to describe the concerns that I had regarding my institution and those at other engineering and technology schools. In discussing these concerns, I raised a number of issues related to the lack of academic preparation of entering students, increasing expectations by employers of our graduates, retaining students, helping faculty to keep pace with technological advancements, and continuing difficulty in recruiting students into the disciplines. In summing my frustrations, Dr. Schuman used the phrase "dying on the vine" to describe the cumulative effect of these concerns in engineering and technology and expressed apprehension as to whether or not a management study would help resolve the problems that I had articulated. It became apparent to me that I would need to look at these issues and those at comparable institutions from a perspective different than a systems approach.

In many respects this dissertation has required that I get back to basics including the purposes of professional and technical education in higher education. There were many things learned during this process, in particular, a reminder that we need to step back from our day-to-day responsibilities to reflect on the mission and goals that form the context of our organizational activities. The process of describing issues as they related to students instead of processes or administrative tasks helped to put into perspective what my colleagues and I could reasonably resolve and provide for our students in an academic environment.

During this process I was able to work with faculty, administrators and students to help me come to a better understanding of a particular problem which in turn allowed me along with my colleagues to initiate and experiment with some of the bridges later described in this dissertation. From this process I was able to gain new insights as to the practicality and relevancy of some of these bridges in providing an education for the polytechnic student.

By-products of this process of writing a dissertation and experimenting and sharing new information with my colleagues at Wentworth, were a revised Vision Statement for our Institution and learning competencies and skill objectives for curricular development, and just this past year, a core curriculum was redesigned for all of the disciplines at the Institute. As part of this process, a number of bridges studied at other institutions were adapted to help student retention. By researching the literature outside technical education, new meaning was brought to current polytechnic terminology such as “hands-on-learning” from previous research on experiential learning models.

It is now clear to me that a management approach would have only dealt with the symptoms and not the root causes. The end result would have been a band-aid approach to solving a problem. This dissertation has been a learning and humbling experience. It has reinforced my previous design problem experiences as an architect that understanding and defining the client's problem, in this case our students, is the critical step to developing workable solutions. It has also reinforced a previous opinion, that creative problem solving at times requires that we step outside our disciplines or away from our day-to-day activities to gain the necessary insights into the problems we are trying to resolve. The lesson for me has been that the abilities, capabilities, learning styles, and adaptability that we attempt to provide our undergraduate students are the same qualities that we need to have as educators and administrators. This holds true if we are going to continue to improve upon the learning experience for our students at the polytechnics.

CHAPTER 1

THE POLYTECHNICS

This chapter will describe the evolution of America's polytechnics based on several forces that have shaped the educational philosophies, academic objectives, curricular structure, and pedagogy within technical education. This chapter will also begin to describe some of the factors that have contributed directly to an expanding gap between the learning skills of entering students and the changing technological applications in the workforce.

Like the many strands that give strength and shape to rope or wire, the polytechnics represent the numerous paths to technical education in the United States including undergraduate (certificate to baccalaureate) and graduate degree programs in design and technology.[1] The name polytechnic was first adopted by European post-secondary schools outside the traditional research universities to represent those institutions or departments involved in the education of engineering and technical professionals. It is a name that has also been used by leading engineering technology schools in the United States and is found occasionally in the literature to reference engineering programs in the journals such as the Journal of Engineering Technology, Journal of Engineering Education, and the ASEE Prism (Troxler, 1991).

To understand polytechnic education, it is important to recognize several influences. These influences, some dating back as early as the eighteenth century, have evolved from the business community, professional societies, scientific and educational communities, and program accreditors. Each have had an impact on the learning environment to the subsequent experiential learning models that developed at the polytechnics. We begin with a discussion of the business and professional communities and their influence on the development of program content and the educational paths within technical education.

Influences From The Professional And Business Communities

A major influence on the development of pedagogy and curricular structure at the polytechnics has been the same creative process used by artisans throughout history to convert an idea into reality, that of learning from a master in that discipline. This 'hands-on-approach' to learning, where students study and apply their newly acquired skills under the tutelage of a skilled person, is a fundamental educational philosophy and objective in polytechnic education. Two of the earliest paths of technical education, greatly influenced by the eighteenth century artisan guilds, included apprenticeship programs, and the more formal vocational and career training programs. Each of these paths has in turn had a lasting impact on the curricular structure and pedagogy presently used in undergraduate and graduate polytechnic education. These paths paralleled and were themselves influenced by the economic growth as the United States moved from an agrarian to an industrialized society.

Apprenticeship and Empirical Learning Methods

Artisan or craft apprenticeship programs emphasized the physical skill and understanding of general work practices and standards found in a particular industry. Brought to the colonies from Europe during the early 1700s, the artisan and craft guilds provided apprenticeship training for young boys to learn a trade such as tool making, stone cutting (masonry), coopering (barrels, wheels and carriages), furniture making, silver making, iron making, printing, and ship-building.

Typically, parents paid the guild or skilled craftsman for an opportunity to have their child develop the necessary skills for a specific trade. At the end of a successful apprenticeship, these apprentices in construction (carpenters and masons), road building, ship and sail builders, textiles, mining and iron working normally stayed on as employees with the shop or master craftsman from whom they received their training. Those that had the ambition and skills to match could continue on with their studies as journeymen and learn more about the advanced applications under this tutelage system. Those who saved enough money to open their own shop or who were able to buy into an existing business could apply through the guild or, in later years, the local government authorities as a master craftsman in their field (Wickinden, 1975).

These forms of empirical learning influenced all later forms of polytechnic education. This method of teaching and learning continues in the form of student internships or co-operative work experiences in a student's major.

> Flexibility in the development of appropriate work experiences, such as a formal cooperative program, as part of the engineering technology program is encouraged. Work experience components will be evaluated as part of the evaluation of an entire engineering technology program (Accreditation Board for Engineering and Technology [ABET], 1994, TAC-ABET Section V.C.7).

In this form of apprenticeship, students are supervised and then evaluated as to their success in applying new knowledge and skills that they have learned in the classroom. The concept of training with a 'skilled master' has also influenced the development of program accreditation criteria by the polytechnics. Included in these criteria were standards for laboratory instruction and the faculty credentials.[2] This concept of learning from the practitioner not only influenced the pedagogy of polytechnic undergraduate education but also the process of becoming eligible to qualify to take state registration examinations. Tutelage or apprenticeship training (three to four years after graduation) is a legislated requirement for those in architecture and engineering.[3]

As the technical fields began to require more measurement, instrumentation, and the use of mathematics, another form and level of artisan or craft training evolved. This new form, called vocational or career technical training, also influenced polytechnic education. Some of these earliest forms of technical training were provided by the professional societies that had developed independently from the trade guilds. These professional societies were first composed of the owners, managers, and professional staff of the industries and businesses hiring new employees into their firms. The societies later expanded their membership to include 'newly educated' practitioners from their educational programs. With the pressure to expand their production efficiencies, many employers began to provide their own on the job training programs by recruiting high school graduates who exhibited strong mathematical skills. This was a change in recruitment strategy by the firms who could no longer obtain a sufficient quantity of trainable workers directly from their production shops or from the workers at the construction sites (Jencks and Riesman, 1977).

The Mechanical Arts and Formal Education

Early in the 1900s, formal vocational or career training programs for the technical work force were developed. These were sponsored by the professional societies that had developed outside the guilds and unions to respond to the growing needs in the work force. Instruction was provided by the members of society who had achieved a certain amount of status, skill, and experience from the firms and recognition by their colleagues within the professional societies. Examples of this type of formal training included the Boston Architectural Club (1867 and now called the Boston Society of Architects) to prepare draftsmen for the architectural and construction firms, Society of Naval Architects and Marine Engineers (1893) that offered courses in shipbuilding techniques and navigation, and the Institute of Electrical and Electronics Engineers (1884) that offered basic electrical subjects (Wickinden, 1975). In the early 1900's these programs were expanded as new professional societies were formed. These new groups included the American Society of Agricultural Engineers (1907) and the American Society of Refrigeration Engineers (1904). Individuals who sought specialized technical training wanted to become drafters, field inspectors, estimators, and engineering and surveying assistants in the new emerging industrial centers from Pittsburgh to Cleveland. These training programs generally attracted individuals seeking employment opportunities in manufacturing, civil engineering, agriculture, and architecture who did not have the prerequisite educational qualifications now expected by employers. As technology relied on more instrumentation and measurement techniques to accomplish its work, formalized training in the application of mathematics and basic sciences became more important and were incorporated into the programs by the professional societies.

As the need for more qualified workers continued to grow in the twentieth century, employers generally found it more practical to again provide their own training rather than rely on the professional societies or the few, for-profit schools offering similar programs. Examples of this training included those programs provided by companies like the American Telephone and Telegraph Company, the utility companies such as electric power, water and gas and a variety of special purpose industries such as steel making, ship-building, railroads and mining. As these programs expanded, a strong relationship did develop between the professional societies and the companies that resulted in the establishment of competency skill objectives and standards of practice. These standards were also created so that employee skills developed at a firm would be transferable from one company to another. An example of this practitioner influence is the Engineers' Council for Professional Development, now called the Accreditation Board of Engineering and Technology (ABET) established in 1932 by fifteen professional societies. This Council continues to regulate technical education in the engineering and other technical disciplines through its member schools who jointly establish minimum educational standards and criteria related to curricular structure, faculty credentials and resources affecting the learning environment (Wickinden, 1975). Members of this council periodically review self study reports prepared by those schools seeking accreditation for their programs and conduct visits to determine if minimum standards are in place prior to making a recommendation for new or re-accreditation for that program. Generally, recommendations are made for the schools to follow-up with prior to any future visits and re-accreditation processes.

As state legislators expanded their control to protect the health and safety of the citizenry, they began to require that the design professionals responsible for implementing numerous public code requirements, such as building codes in construction, become either registered architects or engineers. When first attempting to implement registration and certification laws with those already employed, local politicians sought the advice of the professional societies in the fields like architecture, medicine, and engineering to establish minimum educational and practical experiences for licensing requirements.

As more practitioners in technical specialties were required to be either registered (design professionals like architects and engineers) or certified (like technicians or contractors), the professional societies assumed even more influence and responsibility for the training of their future assistants and colleagues. Eventually, working relationships were also established with those in higher education to regulate and influence curricular structure, course content, and those responsible for program accreditations at the national level. Title and practice registration for architects and engineers eventually expanded to all states by the 1940s. Promoted by the professional societies, national educational and registration criteria for design professionals and technicians have since been adopted by those in academe and by the state legislators. From these standards, reciprocal registration arrangements have evolved to allow members of the professional societies to practice in other states without additional examination. A key to these arrangements is the academic accreditation policies and standards that are strongly influenced by the practitioners.

When national program accreditations became more influential and prevalent in the twentieth century, the professional societies again positioned themselves so that they were a required partner in the academic review process. The professional societies sought to influence the preparation of future practitioners by establishing minimum competency outcomes from the learning experience in higher education. For example, regular contact between the polytechnics and industry was specified as an accreditation criteria.

> An industrial advisory committee is required and must meet at least annually. Records and minutes of the meetings should be written and kept available. An effective committee should periodically review program offerings and course content to ensure that the current and future needs of engineering technicians in industry are being met (ABET, 1994, TAC-ABET Section V.J.).

In this way, the professional societies have continued to shape registration eligibility whether a candidate gains the educational and work experience through apprenticeship or in combination with apprenticeship experience and the attainment of academic credentials through the polytechnics. Today, the professional societies, along with departments of the federal government and the academic societies, continue to formulate policies and procedures to regulate and certify the technical work force from emerging disciplines such as telecommunications, biotechnology, and environmental engineering.

The sum of these influences from the business and professional community has been profound. In the late sixties, the professional societies were so influential that individuals took legal action against state boards of registration accusing them of establishing quota systems with the societies and thus limiting the number of new professionals.[4] These actions forced a more open review of testing procedures and disclosure of the results to the public. The seventies were marked by federal action and law suits against some of the societies for restraint of trade.[5] These suits, while affecting standards of practice, did not reduce the influence the societies had on accreditation groups or the states in establishing registration criteria.

For the polytechnics, the professional societies have strongly influenced the content of programs and courses, defined the relevant practical experiences and values to be included in technical education, and provided the technical faculty to these programs. For the most part, this strong influence by the professional community on pedagogy, course material, and shared professional value systems at the polytechnics has been a rewarding experience for students, faculty, and industry. Release time for a faculty member's scholarly and creative activity were supported by industry and government through the forms of consulting fees and basic and applied research dollars. Some students obtained cooperative work experiences while in school and most were recruited by employers before they graduated from their programs. The firms were able to hire well qualified, productive graduates. Graduate universities had more qualified applications than positions for their academic programs and research projects.

Influences From The Scientific And Educational Communities

A second historical influence that has shaped polytechnic education has come from the scientific and educational communities. As scientific disciplines were added to the curricula at many universities, the scientific method began to influence the techniques of empirical learning derived from the tutelage systems. This has in turn led to new approaches to classroom instruction in technical education. The more positivist view of scientific inquiry has not only influenced the process of learning (Kolb, 1984) but also the way professionals practiced in the technical disciplines (Schön, 1983).

Three prominent paths in polytechnic education emerged in the 1960s. Two of these paths have attracted much public debate by faculty and educational administrators.[6] One path is that of the “engineering scientist” who has been educated at the baccalaureate and graduate levels to work on research and development projects in government and industry. A second path, that of the “engineering technologist”, prepares the graduate primarily at the undergraduate level to apply engineering concepts in related businesses and consulting firms (Thompson, 1987). The third path, and not part of the national debate, is that of the technician who has been educated at the associate degree level to assist both the practitioner and researcher. All three paths were influenced by the previously discussed apprenticeship and post-secondary training programs.

These apprenticeship and vocational or career training programs, referred to as the “shop culture” because most of the learning was expected to occur in the shop or laboratory began to give way to what has been called the “school culture” in polytechnic education (McMath, Bayon, Buttoun, Foster, Giebelhaus, and Reed, 1985). In this culture, learning and skill preparation were dominated by classroom lecture and individual study outside the shop. The following is a discussion of this developing “school culture’s ” influence at the polytechnics.

Evolving Two-Year Technical Programs

Formal classroom instruction, which is now required by most technical disciplines for certification in such fields as welding, operation of power equipment, electrical systems, scientific testing and medicine (biomedical) as well as continuing education credits required by those already certified or have professional registration started to evolve at the turn of the twentieth century. Whereas the former method of craft apprenticeships depended completely on on-the-job training, technical classroom and laboratory instruction replicated the conditions of the work site for a more controlled environment to enhance learning. As previously mentioned, this method of instruction gained quick acceptance when demand for skilled workers increased and the existing apprenticeship programs could not produce a sufficient number of qualified artisans, technicians, or future engineers.

The early technical classroom training programs were provided by 'for-profit' and 'non-profit' schools. Graduates of these programs were then required to seek related apprenticeship positions. These technical programs generally consisted of 700 to 2500 hours of instruction. Eighty percent of instructional time was in a laboratory or shop and focused on the application and technical skill development of the student. The remaining twenty percent of instructional time was intended to compliment application skills with basic and theoretical skills in mathematics, instrumentation, measurement, and specialty applications. However, these private programs were less affordable to an increasing immigrant population in the early 1900s, and many went out of business.[7] Public trade high schools, now referred to as technical vocational high schools, were then created to assist manufacturing centers with their work force needs by supplying technically trained graduates familiar with local industry production processes and equipment.

By the 1920s, a number of 'for-profit' and 'non-profit' technical schools were re-established to meet the growing needs of industry for qualified workers that the public school system could not supply. These technical programs typically required one or two years of study beyond high school. These technical training schools have generally been regulated by those governmental agencies responsible for licensing technicians such as the Federal Aviation Administration Certification (FAA) and the Federal Communications Certification (FCC).

Another path or option to technical education began to develop in the late 1940s to meet the new needs of industry and government after World War II. Typically, these were certificate (one to two years of college study), two-year associate degree programs or three year diploma programs depending upon the academic and practical experience required by the particular industry and the requirements for licensing or registration by the individual states. More recently, community colleges expanded their missions and technical program offerings to meet increased needs in the economy. By 1993, the Engineering Manpower Commission (now called the Engineering Workforce Commission) reported that approximately 40,500 full-time students and 37,300 part-time students were studying in the technical disciplines at the associate degree level. Evolving from the earlier 'time-in class' technical training programs, these two-year technical degree programs required entering students to have a high school diploma, sufficient mathematical skills in algebra and geometry, and an aptitude for 'working with [their] hands (mechanical arts).' The primary objectives of these two-year associate degree programs have been to prepare technicians who would assist the practitioner and to provide a base for further education.

Since the 1960s, a student in a two-year associate degree technical program was in class for approximately 25 hours per week. Forty-percent (40%) of the classroom instruction in these programs were devoted to learning appropriate mathematical and scientific theory through laboratory instruction. Two-year associate degree technical programs also relied on the use of faculty from industry who were experienced practitioners and could explain the various technical processes in the classroom and laboratory. Classroom emphasis was given to assist the student in learning application skills using mathematics and measurement techniques, and discipline-related problem-solving techniques and processes. In some disciplines, graduates of these programs completed certification tests after a required number of hours on the job.

As the number of two-year associate degree programs increased, program accreditations were eventually established to control the expected output at these schools. With the growth of program accreditations in the last 25 years, the curriculum has also included courses to improve a student's communication and lifelong learning skills. These two-year programs have also had an influence on the structure of four-year polytechnic programs and, in particular, the educational path of the 'engineering technologist'.

Many of these two-year schools eventually expanded their program offerings into four-year baccalaureate programs as technologies became more sophisticated and demand by employers for technically trained undergraduates increased. This was generally accomplished by adding two years of theoretical studies in mathematics, sciences, humanities and social sciences, and design applications in the student's discipline to the existing two-year technical programs. As new fields of study were expanded in the late 1970s and throughout the 1980s, many new baccalaureate programs reported by Accreditation Board for Engineering and Technology, Inc. (ABET), were developed as stand alone four-year programs as opposed to 2+2 programs. The 1980's also witnessed an increased number of articulation agreements between community colleges and state and private colleges. These agreements, developed in conjunction with faculty from the participating schools, allowed a student to move directly after graduating from one school with an associate degree into another that was already offering a baccalaureate program without the need to take additional prerequisite courses. This reinforced the process of converting two-year stand alone programs formerly offered at these schools into four-year programs (ASEE and ABET Annual Reports since 1975). This conversion process to baccalaureate technical programs was also heightened by the fact that states were requiring baccalaureate degrees as one of the minimum requirements for eligibility towards registration.[8]

The Four-Year Academic Program

Separate from the development of two-year degree programs, four and five-year degree programs in architecture and engineering evolved at the university level. The following is a discussion of their development within the academic community.

Engineering in America started with the military and grew with the railroads and steamboats (Jencks and Riesman,1977). But the need for formal educational training to meet the growing needs of industry started to influence program development at the universities in the middle of the ninetieth century. As universities embraced the attributes of scientific inquiry and incorporated the scientific method into the then traditional liberal arts curricula, specific courses evolved into legitimate fields of study in the mechanical-arts. Vocational programs at the universities began to appear and prosper by the early 1900s.

Founded in 1802, West Point was the first technical school in America. The first civilian technical school was founded at Rensselaer in 1824. By the late 1840s, Yale, Harvard, and Michigan State College of Agriculture had established scientific departments or introduced programs through the established liberal arts schools. "During the 1850s other colleges followed suit, so that by the time of the Civil War there was something like a dozen colleges that would train future bridge builders, railroad designers, and even in some cases experimental farmers (Jencks and Riesman,1977, pp. 223-224)."

With the Morrill Act in 1862, the development of programs in the mechanical arts became firmly established in the United States as a formal and acceptable educational path. New land-grant colleges were set up throughout the country for the study of agriculture and the mechanical arts. In the east, two new private schools, Massachusetts Institute of Technology and Cornell University, were established using federal funding for studies in subjects related to the mechanical arts.

Two major events radically changed the curricular structure and pedagogy found at these technical schools and elevated their importance to the United States' economy and 'superpower status'. The first was the inclusion of scientific inquiry in the curriculum in the 1950s, and the second was the political need to enhance the United States' national defense preparation by increasing the number of technically educated people in the 1960s.

In 1953, partly influenced by the intervention and success of German physicists who joined the engineering disciplines on defense-related projects during World War II, L.E. Grinter, American Society of Engineering Educators' (ASEE) President, wrote a number of articles on engineering education. These articles focused on the need for greater mathematics and science skills in the undergraduate engineering programs and less emphasis on the previous empirically based instructional methods (learning through repetitive exercises) used at that time for technical training (Grinter, 1953).

As a result of Grinter's writings, scientific inquiry, not empirical learning, became the dominant mode of educational instruction. The development of a core program of study in basic and advanced mathematics, physics, chemistry and other courses to enhance critical thinking and logic skills were introduced.

These theoretical courses were also used to enhance a student's understanding of the engineering design process. As a result, application courses were replaced with generic technical science courses (science applications to technical problems).

The second event affecting engineering education in the 1960s was the Soviet Union's success of placing a man-made satellite into space. This technological achievement raised a major concern in the United States regarding the ability of America's educational system to prepare future graduates for the scientific and technical disciplines in order to respond to a perceived threat to world peace. A special commission was formed by the American Society of Engineering Educators (ASEE) to review the status of engineering education in this country. A major result of this Commission's report (1962), 'Future of Engineering Education,' was that the education in civil, electrical and mechanical engineering was transformed from educating future practitioners in private industry to educating engineering researchers for the defense industry.

Driven by a political emphasis to increase basic and applied research for defensive needs of this country, federal funds were given to qualified universities. The former application-oriented engineering programs in the 1960s became tracks for engineering graduates to continue with their studies at graduate schools to become the future applied researchers or graduate assistants for basic research laboratories. This eventually led to a path in polytechnic education previously referred to as the 'engineering scientist.' Graduates were trained to work primarily on government sponsored projects in academe and industry.

This combination of events left the United States with a void in the education of future practitioners who could apply the knowledge of science and mathematics to the “mundane” civil, construction, environmental, transportation and manufacturing projects in this country. As a result of this fundamental change in educational perspective at the research universities, four-year engineering technology programs evolved from the previous two-year technical degree programs. These new paths to engineering education were strengthened with new resources from private industry and with faculty from the research schools. They flourished because the graduate’s focus was on filling a gap left in the education of practitioners for private industry. It was not until 1986 that engineering and technology schools again began to re-examine and recommend change to their curricular structure based on the needs of industry to compete in the world markets and the declining US economy.

The American Society for Engineering Education’s 1986 report stated that a problem with the educational system for engineers was that graduates of the programs were largely unaware of the steps needed to bring the development of new products from the idea stage to the marketplace and of the vital roles that engineers played throughout this process. The report also noted that employers were looking for qualities in the graduates such as leadership, motivation, flexibility and judgment in addition to the expected technical knowledge skills (Waks, 1994). In the same study it was noted that the engineering technology programs already offered a greater emphasis on current practice than did the engineering programs and correspondingly less emphasis on mathematics and sciences.

As a result of the decline in federally sponsored projects during the early 1990s in the academy and industry, engineering programs have begun to adopt the recommendations in a second ASEE report (1987) and have moved to reclaim their former position in educating practitioners for the private sector. In a report from the American Institute of Architects (1994) a similar reclaiming of practitioners influence on the education of future graduates occurred. Engineering technology programs have also changed by adding more mathematics, science and design courses to their curricula. Despite the different historical paths that led to engineering and engineering technology, these programs have become similar in objectives and approach, causing students and employers difficulty in differentiating between them.

The scientific and educational communities integrated the scientific method into the curricula and have influenced the pedagogy used in today's programs. Empirical learning was formalized, new knowledge was discovered more through research than from the practice of technology or engineering, and theory began to replace "rules-of-thumb" in the design and manufacturing process. "Hands-on-experiences" were replaced with the evolving experiential learning models which will now be discussed.

Influence of the Experiential Learning Paradigm

The influence of the artisan or craft guilds, vocational training, and two-year associate degree programs on polytechnic education was that of incorporating the experiences of apprenticeship training into the curriculum. The need for practical "hands-on" experiences impacted the use of laboratory instruction, faculty hiring practices, incorporation of state-of-the-art methods and design problem-solving techniques used by the faculty in their course content, and the eventual preparation and advising of graduates to seek apprenticeship positions after graduation. Concepts of co-operative work experiences and student internships were all derived from the earlier learning experiences and lessons from these systems.

The attempt to formalize empirical learning experiences with the methods associated with scientific inquiry at the polytechnics is best described by the twentieth century development of experiential learning models. These models have evolved through the writings of the theoretical educators and philosophers such as Schön (1983) and Kolb (1984). These writers have described the dominant epistemology of practice associated with technical education to be that of incremental problem-solving that is made rigorous by the application of scientific theory and technique or what Schön (1987) calls 'reflection in action.'

In contrast to learning through repetition, experiential learning is characterized as a continuous and holistic process grounded in experiences where learning involves numerous transactions between a person and the experience. As a result of these transactions, students and practitioners in technical and engineering disciplines are able to create new knowledge and acquire application skills for themselves that can be later applied to new problems and situations. In this process, called the 'convergent learning style,' abstract conceptualization, active experimentation, problem-solving, decision-making, and the practical application of ideas are emphasized (Kolb, 1984). Architectural and engineering students at the polytechnics are first introduced to the experiential learning process through their design courses. In these courses, they are encouraged by the faculty to explore the design process by acquiring concrete experiences (testing, measuring, and replicating existing products or services), reflecting on those experiences and making observations (data collection and analysis), abstracting and deriving new ideas and conceptualizing other models for future use (design through a process of synthesis), and actively experimenting to discover what is possible or not (testing of constructed models). This experience is further enhanced when students are able to work on problems that are current in their disciplines (applied research, case studies, or student competitions). In first year architecture programs there are several examples of this experiential learning process. One such design project is that of translating an emotion into three dimensional space.

The student is required to select an emotion (delight, fear, stress, etc.) and then define that emotion in terms of materials (color, texture) and shapes (scale, form) that will generate that same feeling in others. Working from what the student thinks he understands, he must now test that out with others, by developing a methodology including an analytical approach that will help develop confidence in his current understanding of what physical items will generate a similar response in others. Based on this information and testing he will begin to select other materials and form a new understanding from these additional experiences. Eventually, the student will be required to translate these experiences into concrete design solutions (drawing and by scale model).

This process forces the student to bring his preconceived notions out and then compare them to the reaction of others. In this process, the student works directly with a faculty member and then his cohorts. In addition to individually challenging certain beliefs, the architectural process also requires the student to present to other students their solutions and defend these solutions opinions based on tested information and analysis. After an initial selection by the faculty and students some of these solutions are actually constructed to full scale. Through the act of construction (converting ideas into reality or architectural synthesis) all students learn from experience whether or not these selections, design and constructions evoke the type of emotion originally planned. This new knowledge and experience is then again brought back by the students and used in the next design project. A similar approach is used with engineering students. Generally, the design solutions are more mathematically generated, yet students are required to measure, test and compare their results. The best publicized of these projects are the first design projects held a MIT in which student teams compete to create machines to do some type of task with limited materials and a set of design parameters.

In their article on applying experiential learning to engineering and technical education, Svincki and Dixon (1987) have identified appropriate instructional methods that support this process and that are already being used at the polytechnics. Some of these techniques include laboratories (about 20-40% of the work in class), computer simulation techniques, case studies from industry, design projects, conceptual model building and field work, to name a few. The primary differences between experiential learning techniques to instruction and those previously developed from apprenticeship and empirical learning models is that there are no correct answers to solving problems. In the experiential model, students would not be taught to memorize standard problem types in which standard solutions could be applied. However, different problems would be studied and analyzed for their unique characteristics and then, based on previous attempts to solve other problems, a solution would be constructed and tested. Given the rapid changes in the work force, the previous work of Grinter (1953) and the scientific community, and the writings of Kolb (1984) and Schön (1983), experiential learning models have begun to replace the previously developed empirical models of learning at the polytechnics.

Influences From The Program Accreditors

Various program accreditors have also influenced the educational models at the polytechnics. These organizations are comprised of members from related professional and educational societies and those member schools seeking accreditation. The primary accreditation organizations at the polytechnics include the Accreditation Board for Engineering and Technology (ABET), National Architectural Accreditation Board (NAAB), and the Foundation for Interior Design and Research (FIDER). These organizations accredit both the professional (leading to registration) and para-professional degree programs. Although accreditation is a voluntary process for the institutions offering the related programs, candidates for admission use program accreditation as one criteria when selecting a school and comparing academic quality. State agencies charged with the responsibility for professional registration also use program accreditation as a minimum prerequisite for candidate eligibility for practice registration. Federal and state funding agencies generally require that institutions have appropriate accreditations before being eligible to receive government funds. Having an accredited program also influences the status of faculty at national and regional organizations related to their fields.

Typically, schools seeking accreditation complete a self-study report based on the standards at that college, prepare additional materials such as course manuals and student work for peer review by a visiting team of professional and educational colleagues, and prepare for interviews by the visiting team. These interviews will be conducted with graduates, faculty, students, industrial advisors, employers and staff. The purpose of this process is to determine if the (re-)applying school has met the standards of the accreditors, has achieved its program objectives, and has sufficient resources to support its learning environment. Although accreditation is a voluntary system by the polytechnics, failure to gain program accreditation can negatively affect the undergraduate's ability to pursue professional registration or further schooling as well as limit the faculty's ability to acquire research or foundation dollars.

Over the years, faculty and administrators have complained that some program accreditors are more interested in establishing a national curriculum than they are in helping the member school achieve its objectives. The increased influence of the national professional societies has caused some schools, like MIT and Stanford, to openly criticize the process and threaten to pull out of the association altogether (Timmermann, 1991). For example, some criteria are so specific that they define and prescribe what a school's program, purpose and content should be.

> An engineering program is an organized educational experience that consists of a cohesive set of courses or other educational modules sequenced so that reasonable depth is obtained in the upper-level courses. A definite engineering stem should be obvious in the program, and, again, depth should be reached in pursuing courses in the engineering stem. Furthermore, the program should develop the ability to apply pertinent knowledge to the practice of engineering. An engineering program must also involve the broadening educational objectives expected in modern post-secondary education (ABET, 1994, EAC-ABET Section II.A.1).

The curricular structure at the polytechnic schools is controlled rigidly by the standards of accreditation groups such as ABET, NAAB and FIDER and by the secondary criteria established by the participating professional societies that are associated with a particular discipline. For example, the Engineering Commission on Accreditation of ABET requires that all baccalaureate programs must have courses based on the minimum of one year in mathematics and basic sciences, one year in technical sciences (mathematical and science applications to a discipline), one half year of humanities and social sciences, and one half year of design and application. Additional criteria include laboratory experience, computer based experience, probability and statistics, written and oral communications, and an understanding of ethical, social, economic, and safety considerations in engineering practice (Engineering Accreditation Commission of ABET).[9] Remedial courses are not allowed to be counted as any part of the above requirements. Again, specific accreditation criteria prescribe what courses can and can not be used in a schools curricular structure.

> Engineering is that profession in which knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind. A significant measure of an engineering education is the degree to which it has prepared the graduate to pursue a productive engineering career that is characterized by continued professional growth (ABET, 1994, EAC of ABET Section IV.C. 2).

In addition to minimum course work, accreditation standards also emphasize minimum areas of skilled-based competency in technical problem solving, an ability to maintain professional competence through lifelong learning, and an understanding of the practitioner's responsibility related to public health and safety.

In their study of professional education, Argyris and Schön (1974) describe the dominant curricular pattern as "real knowledge that lies in the theories and techniques of basic and applied science (p.27)." They go on to state that concrete problem solving skills can not be taught until the student first learns how to use the relevant applied science skills. They list three components to professional knowledge. First, an underlying discipline or basic science component where in the practice rests. In the ABET standards this consists of the basic mathematics and sciences as well as the courses in the humanities. The second is the use of applied science or an engineering component from which many day-to-day diagnostic procedures and problem solutions are derived. In the ABET criteria, this is translated into engineering science courses that directly apply the mathematics and basic sciences to the design engineering process. The third includes skills and an attitudinal component that concerns the actual performance of service to the client, using the underlying basic and applied knowledge. Typically, in the ABET criteria and standards, this includes the course work in engineering design and other related professional courses and electives.

Professional education and the accreditation standards reinforce a common set of values and beliefs that shape the practitioners problem solving style through acquired habits in a student's academic and professional training courses. There is the attempt to control the means of performance rather than outcomes once a graduate leaves (Kolb, 1984). Within this educational paradigm, four professional competencies are developed and integrated throughout the curricular structure and pedagogy. They include: conceptual competencies - an understanding the theoretical foundations; technical competencies - an ability to perform skills required of the profession; integrative competencies - an ability to meld theory and skills in the practice setting; and, career marketability - the graduate becoming marketable due to acquired education and training (Stark & Lowther, 1988). Polytechnic education also attempts to supplement purely technical and conceptual competence with concerns for adaptability, leadership potential, and motivation for continued improvement of the profession and of one's self as a professional (Stark and Malcolm, 1988 and, ASEE, 1994).

Graduation from an accredited baccalaureate program by ABET is a prerequisite for state registration examinations and acceptance into approved Engineering-In-Training (EIT) apprenticeship programs needed to become a registered professional engineer. A similar condition exists nation-wide for architectural registration. Exam candidates must graduate from a nationally accredited program (National Architectural Accrediting Board [NAAB]) before being eligible for the required apprenticeship program and then taking the professional exam. Some of these programs are also a prerequisite educational requirement for certification with national business and governmental organizations such as the National Institute of Certified Engineering Technicians (NICET), Society of Manufacturing Engineers (SME), Federal Aviation Agency (FAA), Federal Communication Commission (FCC), American Concrete Institute (ACI) to name a few. There are also a number of specialty certifications and licenses that also require a baccalaureate education from an accredited program offered at the polytechnics to practice in fields such as environmental and nuclear engineering. Again, all these specialty requirements reinforce the perception by the individual universities that professional and educational societies are attempting to create a national curriculum and causing some schools to rethink the value of program accreditations.

These complaints aside regarding accreditors attempting to create a national curriculum, there is in fact a consistent educational theme among the polytechnic schools and supported by their individual mission statements. In a survey of faculty conducted by ASEE across eight (8) undergraduate polytechnic fields the following shared goals had emerged: communication competence, critical thinking, contextual competence, aesthetic sensibilities, professional identity, professional ethic, adaptive competence, leadership capacity, scholarly concern for improvement, and motivation for continued education (Stark and Malcolm, 1988). Not surprisingly, these goals are reinforced by the ABET accreditation criteria for polytechnic curricula.

In addition to minimum course work, accreditation standards also emphasize minimum areas of skilled-based competency for technical problem solving, an ability to maintain professional competence through lifelong learning, and an understanding of the practitioner's responsibility related to public health and safety.

The previous discussions examined the influences that have shaped the development of the many paths to a polytechnic education. The following is a composite characterization of the polytechnics today.

The Polytechnics Today

According to the American Council of Educators' Fact Book (1992) and the National Center for Education Statistics (1991), there were approximately 1,043,000 baccalaureate degrees awarded in the United States, of which 74,500 bachelor degree went to graduates from the polytechnics. The 1993 Engineering Manpower Commission Report (recently renamed the Engineering Workforce Commission) on technical education reported that there are 379,912 full-time and 77,848 part-time undergraduate students studying at the polytechnics. These current demographic numbers reflect an 18% decrease in the total number of people studying from a previous high in 1988 (ASEE Annual Reports). Based on a ASEE 1994 Report, this rate of decline is now only 5%. Due to previous demographic declines, a 6% annual decrease in the number of students studying at the polytechnic schools is expected to continue until the year 1997 when the number of high school graduates starts to increase again

(Gerald and Hussar, 1991). Since 1988, students taking the PSAT exams in high school have indicated an additional decline from 8% to 5% of those interested in studying in the science, engineering and technology disciplines (College Boards, 1993).

There are presently 302 schools in forty states offering engineering technology programs and another 336 schools in 50 states offering engineering programs (ASEE, 1994). In architecture, the number of accredited schools rose from 98 to 115 while the population of incoming students declined by 10% (American Institute of Architects, 1994).

Internal and External Factors Contributing to the Learning Skills Gap

During the 1960s and 70s, the polytechnics were able to attract a sufficient number of well-motivated and educationally prepared students into associate and baccalaureate degree programs. Beginning in the 1980s, fewer of the best high school graduates were inclined to enroll in these disciplines. Many more students who were less than prepared for the mathematical and scientific rigors of technical education have enrolled in the programs. Despite efforts to accommodate today's entering cohorts (which will be discussed further in Chapter Four), student attrition remains above 40% according to reports by the National Science Board and the American Society of Engineering Education. While the college preparatory skills continue to diminish, external pressures from employers and the accreditation agencies to add more material to the curriculum have increased.

Because of the curricular load on students, it typically takes a full-time student four and one half (4-1/2) to six (6) years to complete the specific graduation requirements at the polytechnics. Twenty-nine percent (29%) of the polytechnics require a minimum combined SAT score of 850 for admission consideration, although there are a number of students who are being admitted with less ability to fill seats in the classroom. Most other polytechnics have not published their minimum requirements. Other basic admission requirements include a minimum of three (3) or more years of high school mathematics including algebra, geometry and trigonometry and three (3) or more years of basic sciences including laboratory experience in physics or chemistry.

Students at the polytechnics are typically in class for 18 to 24 hours per week. Of this time, 80% of the classroom instruction is devoted to learning basic and applied theory while 20% is laboratory related time used to develop an individual's skills in instrumentation, measurement and technical application in the engineering or architectural design process.

Summary And Conclusion

Polytechnic education has been shaped by the historical relationships with the needs of the professions, industry and government, the rise of program accreditors, and the influences on pedagogy by apprenticeship training programs, scientific inquiry, and experiential learning models. In each technical discipline, certain conceptual understandings and technical performance standards have dictated unique skill and professional competencies that are of primary concern to educators. The current educational approach reflects the traditional view of professional practice as the systematic application of a set of standardized concepts and analytical methods to a recurrent problem in order to arrive at a unique solution. (Moor, 1970).[10]

Polytechnic education has borrowed much from the early craft and technical apprenticeship programs in which new practitioners learned their skills directly under the tutelage of a skilled person. This philosophy continues on in the many professional disciplines at the polytechnics including architecture, engineering, and in the allied para-professional disciplines such as field and laboratory technicians and drafters. Based on a combination of government regulations, technological change, economic competition, national needs such as defense, and new understandings and knowledge related to design and production planning, professional practice became more sophisticated. As a result, empirical learning models or "shop cultures" at the polytechnics began to give way to the "school culture" as more scientific approaches were included into each profession's problem solving process. Adapting, the polytechnics not only included scientific and mathematical inquiry into their bag of tools but also adopted from higher education the concepts of experiential learning models. Protecting the disciplines and regulating the numbers as well as the quality of those who could practice, professional societies and program accreditors exercised and influenced much control over those who were providing the educational programs.

During the past 50 years, the polytechnics flourished as a result of a symbiotic relationship among government, industry, and society. However, turbulent world events have radically changed that status quo. In the United States, a technical workforce is being replaced with a service workforce, government spending for applied and basic research in science and engineering is on a decline, support for secondary education continues to decline, and societal priorities no longer converge with technical needs. As a result, there is now a conflict in the agendas (primarily based on policy and funding issues) between the citizenry, politicians and business.

Some of the factors contributing to this conflict in agendas and affecting the polytechnics are both numerous and complex. The lack of a comprehensive and consistent government policy requiring competency-based high school education has resulted in declining entry skills of potential students to pursue careers requiring mathematics and sciences. Societal changes, such as those occurring with the family structure and the eroding of parental support to the development of their children (Futrell, 1993), the increasing mistrust that citizens have for government agencies and other institutions, a current economic recession that has eliminated a number of professional worker positions, and the continuing increase of costs for a technical education have collectively contributed to a decline in interest at the polytechnics.

This conflict translates into fewer qualified students applying to the polytechnics to study disciplines in science, engineering and technology and has left the polytechnics in a position of having to accept students who are less-than-prepared academically to study in the technical professions. This challenge to the status quo has both interrupted the previous flow of new and academically qualified students seeking an education at the polytechnics and is placing in the workhorse generation of graduates who are less prepared than before to compete in today's world markets. In addition to conflicts of agendas within this country, world events have also brought change to the number of new positions and skills expected by employers of polytechnic graduates causing some students to reconsider their academic and career objectives in science, engineering and technology.

As a result of this declining interest by high school graduates, the polytechnics can no longer attract a diversity of skilled and talented people from industry or academe to teach its undergraduates. Recruitment of meritorious students has changed to competing for "bodies" to fill the empty seats. Reduced government and industrial spending on research projects have reduced dollars to support undergraduate polytechnic education. Since many of the technological positions have left this country, there is less demand by industry for the undergraduates. Many of the polytechnic laboratories have become obsolete, there are fewer people willing to come to the polytechnics to teach, and the faculty who have remained have not been able to keep pace with the changes in their profession.

Changes associated with technology and the future work force will be discussed in Chapter Two - The Technical Workforce. Problems associated with the preparation skills of today's incoming students to the polytechnics will be discussed in Chapter Three - The Polytechnic Student.

Chapter 1 End Notes

1. Traditional fields of study at the polytechnics have included aeronautical, architectural, chemical, civil, electrical and mechanical engineering. Examples of the ninety-plus undergraduate engineering and technology specialties listed by the Accreditation Board for Engineering and Technology, Inc. (ABET) include biotechnology, construction, computer hardware, nuclear, environmental, geo-technical, material science, electronics, manufacturing and transportation. Other specialized professional and technical accreditation groups that regulate academic programs and practice in the United States include the National Architectural Accreditation Board (NAAB), Foundation for Interior Design and Research (FIDER) and the American Council for Construction Education (ACCE) to name a few.

2. Professional program accreditors like EAC of ABET- engineering, TAC-ABET- engineering technology, NAAB- architecture, FIDER- interior design, and ACCE- construction engineering and management have each specified faculty

credentials in terms of degrees in the discipline, minimum years of related practical experience, and in some cases expected professional registrations or certifications.

3. In most states, to be eligible for the professional engineering exams, a candidate must be a graduate of an accredited bachelor degree program, have successfully taken the fundamental examination (FE Exams) after graduating from college (or in their last semester of college), and worked directly for a registered professional engineer for at least 4 years.

4. A suit brought against the Massachusetts Registration Boards related to architects and engineers in 1973 required public disclosure of the grading practices of the national exam and the minimum passing grades .

5. The Department of Justice brought suit with the American Institute of Architects (1985) and caused the profession to modify its code of ethics and practice.

6. Although there continues to be much discussion between educators from engineering and engineering technology regarding the differences between their baccalaureate programs, graduates from their programs presently compete for the same entry-level positions in business, industry and government and bring with them comparable learning and technology skills to the job market.

As the nature of work in the engineering profession continues to change (as will be discussed in Chapter Two) and as competition among these related schools increases to attract fewer qualified students and faculty, these two approaches to engineering education have also moved closer together. These two baccalaureate paths will be further described in this chapter, but since the issues affecting the quality of undergraduate engineering and engineering technology education are essentially identical (Mott, 1992), the term polytechnic is used to refer to both of these forms of technical education.

7. As a result of this vocational legislation, many for-profit technical training schools went out of business, and many non-profit schools who were offering certificate training for engineering assistants found themselves in direct competition with these new public schools. In some instances, existing non-profit proprietary schools sought charters from the states to provide two year associate degree programs.

8. In the 1940s, many high school graduates interested in a professional career like engineering or architecture had already gravitated to the bachelor degree programs as the preferred educational path to professional registration. At that time, those thinking of a career as a practicing architect or engineer had a choice to go to college for four or five years then acquire three to five years of professional apprenticeship to be eligible for the registration exams. A second choice was for the those interested to acquire thirteen to fourteen years of professional apprenticeship to be eligible for the exams. By 1988, the apprenticeship path only to professional registration had been all but eliminated through recommendations by the professional societies.

9. Similar requirements are stated by the Technology Accreditation Commission of ABET for baccalaureate technology programs except there is more emphasis on applications and less on design.

10. Although this positivist view has become the hallmark of the professions, educators have begun to call in question this approach and its appropriateness to solving problems requiring technological solutions (Lynton, 1991, Schön, 1987, and Tobias, 1992).

CHAPTER 2

THE TECHNICAL WORKFORCE AND WORKPLACE

This chapter will examine the numerous changes that have occurred in the technical workplace and that have a significant impact on the current and future technical workforce. So significant have been these changes, that previous middle management positions in the technical workforce have been eliminated requiring organizations to rethink, reinvent and eliminate many of the processes that, just a short time ago, were essential to how a company could compete. For example, although manufacturing jobs have been on a steady decline for the past decade in this country, productivity and output have exceeded those jobs when the workforce was twice its size (Steeves, 1991). Not only is manufacturing seeing these types of dramatic changes, but so to are the many other engineering and architectural disciplines that make up the programs at the polytechnics. At the polytechnics, these changes mean that new academic programs are needed to address the interdisciplinary problem solving approaches within their industries such as the emergence of electromechanical engineering (formally two different disciplines in electrical engineering and mechanical engineering), and telecommunications engineering (formally electronic engineering and computer science) to name a few. The challenge to the polytechnic is that the previous processes of how technical problems were solved and by whom is changing radically. The danger is that graduates are not being prepared for these workforce or workplace changes. Given that they are also coming into the programs less prepared academically to deal with the current level of sophistication to learn the technologies, this places an additional burden on the polytechnics and eventually the firms hiring the graduates to compete in the long term. Again, the changes going on in the professions are not merely job title changes but are fundamental changes to the technical organization's work processes and expectations for remaining competitive as an organization. At present, the polytechnic programs are structured to develop an individual not a contributing team member and future leader that is now expected in the technical workforce.

> A decade or so ago, $2-an-hour worker in South Korea became competitive with $15-an-hour blue-collar worker in Bridgeport, Conn. Now, the $3,000-a-year computer hardware engineer in China's Pearl River Valley is breathing down the neck of the $45,000-a-year hardware engineer on Route 128 (Harney, 1993, p. 15).

Forces of global competition, new and rapid developments in technology, deregulation, slow economic growth, and consumer pressures for quality products and services at reduced costs are forcing organizations to change the methods and expectations for doing business and surviving in today's economy. Efficiency is driving companies to rethink the existing work processes that have created and delivered goods and services to the consumer in the past. Results of this rethinking have caused some organizations to eliminate organizational layers. This in turn has resulted in reductions of staff by one-third to one-half (management and production people), increased levels of the incorporation of technology to replace previously labor-intensive tasks, or simply the identification of better ways to do the same thing through incremental changes in work processes. Examples of these techniques have included approaches such as Total Quality Management (TQM) and radical breakthroughs in work design such as with Reengineering concepts (Byrne, 1993, Hammer & Champy, 1993). Other industrialized nations, like Japan and Germany, have shown that the ninetieth century's division of labor developed in the United States has become obsolete. Professionals and technical staff are called upon to perform tasks for which they have not been educated (Schön, 1983). Current turbulent market conditions are also forcing new partnerships among disciplines and groups within existing organizations and between organizations that have traditionally been in competition with each other. Previous formal organizational lines based on disciplines, accountability, responsibility and decision-making have overlapped, disappeared or merged (Peters,1988). Organizations are attempting to become lean and agile by doing more with fewer resources.

Organizations that attempt to develop world-class products or provide world-class services require a world-class labor force (Doyle, 1985, and Reich, 1993). Polytechnic education continues to be one of the major providers of graduates to the professions and industries who are dependent upon technologies to bolster their productivity, competitiveness, and economic growth. But technological and organizational change also result in some skills becoming obsolete and leading to worker displacement and unemployment (Flynn, 1989). Rapid change in industry has also created a skills gap for graduates of the polytechnic schools who were educated and trained in a particular discipline and specialty, based on former processes within their professions and industry. As a result of these ongoing changes in industry, expectations for the new polytechnic graduates now parallel the forces in business. These forces must intensify innovative techniques to solve client needs, adapt to new and emerging technologies, be more productive in constantly changing organizational structures, and have the ability to address the complex social and competitive forces in a global economy. However, not all business organizations in the United States have accepted and adapted to these global forces.

Workforce Changes

In the report, America's Choice: High Skills or Low Wages (National Center on Education and the Economy, 1990), the authors report that the majority of businesses in the United States still characterize their workforce needs as selecting individuals who are prepared to do simple tasks that management will assign and will report on time for their job. The automobile industry serves as an example of this view and an industry that has yet to address the forces of global competition and innovation. In the book Made in America (Dertouzos, Lester, and Solour, 1989), a story is told of how other countries have utilized the workforce for global competition and how they have utilized people as a resource to the organization and not as a consumable item.

> The mass-production of automobiles was invented in America and has become the nation's largest industry. It is also the major customer for many other industries, including alloy steel, aluminum, rubber ,and machine tools. Yet imported cars have risen from less than 1 percent of sales in 1955 to more than 31 percent in 1987. In the 20 years since 1967 the United States has gone from an auto export surplus to an auto import deficit of $60 billion, the largest single element in the overall trade deficit.
>
> Many explanations have been offered. The American car companies did not foresee the oil crises of the 1970s and

the resulting shift in demand to smaller cars; Detroit had little interest in producing small cars because profit margins were low.

But the roots of the problem go still deeper. A system of production and an accompanying market strategy were developed by the American auto industry in the 1920s and perfected over the next 40 years. The American success was built on a few simple axioms. Labor was a commodity to be hired and fired as demand rose and fell. Suppliers were treated in much the same way as the workforce; they were both marginal elements of the production system, utilized in boom periods but jettisoned during the troughs.

For 40 years it was a system that worked brilliantly, but it works no more. The Japanese have found a better way. The Japanese pioneered flexible manufacturing, in which a plant can shift in minutes from the production of one model to another. Continuous incremental improvements were every worker's major job. Because workers could not be laid off, human resources became a strategic asset. Above all, assemblers, workers, and suppliers were all on the same team (pp.18-19).

Other examples of America's loss of technological leadership include the steel and electronic industries, once the strongest contributors to export trade and the gross national product (GNP).

The American steel industry was once the largest, most modern, and most efficient in the world. In the postwar decades the domestic integrated producers lost their technological lead. They failed to adopt quickly the newest technologies, such as the basic oxygen furnace, continuous casting, and computer controls, as these became available in other parts of the world. The firms lacked an international perspective and were characterized by a mature, relatively inflexible organizational structure.

> Microelectronics began as an American industry. Yet America's share of the microelectronics market is falling rapidly. Today the three leading merchant (*makers of computer-chips for others*) semiconductor companies are all Japanese. These companies, which only produced 4% of America's semiconductor products in the past, now supply 94% of that market (Dertouzos et al,1989, p.14).

Instead of bringing to the marketplace the advances from America's basic and applied research, we chose, as a nation, to sell these ideas to others, protect existing industrial 'turf and market share", and ignored the technological and organizational advances made by other nations. An example of this problem is the electronics' industry, in particular the computer chip industry in which the United States went from sole provider world-wide to where it now is dependent on other countries for its supply in the manufacturing of consumer appliances. The United States General Accounting Office survey in 1986 suggested that failure of US firms to adopt new technologies and processes, relative to other industrialized countries, contributes more to job displacement than the rapid adoption of new technologies (Bernstein, 1986).

The United States, once the sole leader in the world in technology, is no longer able to compete as a world producer in several industries including the production of the computer chip, advanced materials, tool-making, and much of the electronics industry for consumer products. While US firms have resisted changes, other industrialized nations have already asked the basic questions regarding their economic future and have begun to prepare their technological workforce to compete globally (Dertouzos, Lester & Solow, 1989). Based on this planning and the dollars invested already by those countries, the United States is expected to lose or not be able to compete in future technologies that could bring economic growth to this country. The United States now finds itself in a vulnerable position. Continued decline of the remaining leading industries and a workforce that is not prepared to compete globally in technology, will continue to down-grade the quality of life in this nation and substantially add to this nation's overall financial debt to other nations. In the future, our current technological workforce could easily become the 'cheap' workforce for other nations. Given current reports as to the level of illiteracy in this country (Wilkie, 1993) and the fewer number of new students reported by the College Boards (1993) as being interested in science, engineering or technology careers (from 13% of those taking PSAT tests in 1985 to 5% in 1993) we may be closer to this prospect of 'cheap labor' than we realize.

Workforce Changes And The Polytechnics

Despite these changes described in the workplace and globally, the suppliers of students to the polytechnics have themselves failed to keep pace.

> Recall that America's educational system at mid-century fit nicely into the prevailing structure of high-volume production within which its young products were to be employed. American schools mirrored the national economy, with a standard assembly-line curriculum divided neatly into subjects, taught in predictable units of time, arranged sequentially by grade, and controlled by standardized tests intended to weed out defective units and return them for reworking. By the last decade of the twentieth century, although the economy has changed dramatically, the form and function of the American

educational system remained roughly the same (Reich, 1993, p.226).

The polytechnics, like the industries that they serve and emulate, have also been slow to understand the forces of global competition. While student demographics were declining overall, in the 1980s the polytechnics slightly increased their student populations. With that increase in student population, they failed to broaden their own undergraduate programs' objectives to continue to attract qualified students into their programs and did not seek ways to upgrade faculty experiences in the workforce. With the growing population of less than academically prepared students graduating from high school, polytechnics had also been slow to adopt needed pedagogical and technological changes into the learning environment to improve teaching effectiveness.

As a result of the polytechnics' short sightedness in addressing the above issues, curricular structures, methodologies and pedagogy, restrictive accreditation agencies and, many times, a professionally outdated faculty, cause the polytechnics to continue to educate its students for careers and positions that will no longer exist in this economic and competitive environment of the future. Typically undergraduates from the polytechnics are either being prepared for technical skills that no longer fit current work processes, or for positions that are disappearing from the job market altogether. Worse, many undergraduates are not being prepared for the necessary learning, communication and behavioral skills that will be needed in the workforce.

Additionally, the polytechnics have also failed to work with the accreditation groups and professional societies to collectively address these national concerns. Maintaining the status-quo in education and protecting one's area of expertise and specialization has taken over the need for a multi-discipline approach to solve related societal and economic problems.

The Technical Workforce Paradigm

In the workforce of today and tomorrow, there is a paradigm shift that is taking place. Jerry Monson, Vice-President of Minnesota Riverland Technical College (Staff, 1992, p.21) has characterized it as follows:

A Paradigm Shift: Manufacturing 2002

Old Paradigm	New Paradigm
Inspectors responsible for quality	Workers responsible for quality
One worker at one machine	Self-directed work teams at machines
Static job assignments	Worker empowerment
"Management thinks, you do"	"Management and workers think and do"
Quantity over quality	Quality over quantity
Price and supply	Quality and customer service
Competition	Collaboration
Collusion/antitrust	Manufacturer networks
Individual incentives	Group incentives
"Let the buyer beware"	External and internal customers
Local orientation	Global orientation
Single-job skills	Job clusters/ skill families
Muscle Power	Smart machinery
Individual efforts	Partnerships
Sporadic training	Constant training
"Degree" education	Lifelong or competency-based learning

Much of this paradigm shift has been the result of successful applications by other industrialized countries that have taken away substantial market shares and leadership previously found only in the United States. This shifting paradigm has also been influenced by Charles Demming and his followers in the areas of Total Quality Management (Entin, 1993). A basic assumption to this new paradigm is that continuous improvement to exceed customers' expectations can be achieved by empowering people to improve the systems of production and delivery. This new work paradigm also requires a shift from the current educational system's focus on learning problem-solving techniques that are repetitive or seeking discontinuous breakthroughs through basic research and patent development projects, and to a system design approach that relies solely on individual initiatives, competence and creativity. In manufacturing, the lessons learned from competitors world-wide have begun to reshape America's production industries. It is still not un common to have a series of specialized departments within an American manufacturing organization, each dealing with a specific need from their customer. Generally this means that the organization hire the best people qualified to do one or two tasks. However, with this system, the global needs of the customer are never addressed such as the need to coordinate new production efficiencies and approaches to save the customer in their operating costs (maintenance, training or personnel to operate equipment or processes). Each of these items are seen by the manufacturer as a problem for the customer to resolve. With Japanese and German manufacturers there is a different approach. The manufacturer in these countries see themselves as solving all of the related needs from design, production to operation associate with the product they are selling. Engineers, production people and marketing people from the same firm form a team to sit with their client and solve the larger and specific problems. In affect it becomes a turn key operation so that the client can focus what it is they are doing and don not have to become expertise in something else. In this country, firms like Boeing have begun to integrate a process into their organization that require that the client be a part of the original design of their new planes as opposed to Boeing creating a plane and then looking for customers. This requires individuals who can think beyond their own specialties, work with others, and develop innovative approaches to remain competitive (Steeves, 1991).

This shift in paradigm is in marked contrast to the former expectations by firms that typically sought out new polytechnic graduates who had a technical specialization and an ability to be productive within a few weeks or months on the job, exhibited a strong ethic for working hard, were able to follow directions, and were reliable. Now firms are looking for people who have the prerequisite learning and technological skills to advance and adapt to changes in the organization, can perform complex tasks, have the interpersonal skills to work in teams and collaborate with others, have a sense of the marketplace, and can articulate their thinking to others in and outside the organization. Attitudes of business and government are also changing regarding the organization's long-term commitment to the development of the firm's human resources. Human talent is no longer perceived as a disposable resource but one that requires nurturing and new investment (National Center on Education and the Economy, 1990). Continuous training at all levels of the firm, not native ability, will be the measure of success in the future.

Other workforce changes that are occurring as U.S. firms attempt to become more competitive globally are also affecting the educational paradigm at the polytechnics. Learning from their major competitors, Japan and Germany, U.S. organizations are shifting their business strategies from the short-term financial tactics used in the past to planning for the long-term survival of a company (Clough, 1993, Galvin, 1994, and Magaziner, 1992). At the polytechnics, this will require new thinking regarding the offering of professional practice and business related courses in the curriculum. Recognizing the value of human capital and the 'thinking skills' required to prepare for the long-term needs of the firm, organizations are making additional and new commitments to the education of their workforce over a longer period of time (Thennien, 1993). For the firms, this means that they are selecting human talent that will be able to continue to learn and adapt to economic and technological changes. The impact of these changes will require that some of the polytechnics re-think their educational missions, assess their educational and curricular objectives and adapt their current undergraduate programs to meet the new challenges facing the technical workforce and workplace. The relationship and complementary nature of specialized technical education to general education courses will need to be reexamined as the polytechnics prepare graduates for the rigors and demands for continuously learning outside the formal classroom and throughout a practitioner's career. Undergraduate education, especially by the educators at the polytechnics, will need to be seen as the first step, and not the only step, in developing a valuable employee and contributing citizen.

It is generally acknowledged by those firms that are able to survive and prosper in today's competitive environment that technical knowledge alone is not sufficient to be competitive. What is required is that the organization use this knowledge to place more emphasis on service, cycle time (time to bring new products to the market place), and manufacturing excellence (Fierman, 1992, Flynn, 1989, Harney, 1993, and Kneake, 1994). The need for a firm's human resources to be more productive and innovative will require not only the prerequisite technical skills but also business acumen and an ability to work more efficiently. In educating the future practitioner at the polytechnic, the faculty will need to emphasize to their students that they must go beyond just applying the learned standards of professional practice within their discipline and step out of the 'cook book' routines to problem-solving learned in the classroom and on the job. Students will also have to develop a better appreciation for the fact, that a technical solution is not complete until it can be produced and 'sold'.

Another lesson that has been learned by U.S. firms is that their employees need the technical and personal skills to become flexible and adaptive, particularly in their willingness to continue to learn and take a more active involvement in managing their own careers (Kuttner, 1992, Lynton, 1991, and National Center on Education and the Economy, 1990). For those seeking that first position in a profession or industry, there is a need to view their undergraduate degree as only a start to their professional education. For those responsible for educating the future practitioner at the polytechnic, this means that educators must help students develop the necessary motivational and risk-taking skills to make decisions in a turbulent environment. Extending this need of individuals to be flexible and adaptive for personal success, the future will belong to multi-domestic companies that combine national nimbleness with international vision and financial clout- that is, think global and act local (Dorato and Abdallah, 1993, Otala, 1993, and Pickert, 1992). For the graduates of the polytechnics, this means that keeping pace with technical advances from around the globe and applying new research to existing problems will be critical to their company's survival as well as to their own career ambitions.

Adapting To Change

For most organizations today and parenthetically the polytechnics, adapting to this new work paradigm and these attitude changes will not be immediate and will be painful. In some cases, the new work paradigm has already revolutionized the form and structure of American companies. In his book, The Work of Nations, Reich (1992) portrays the changes that have already occurred in the so called American industries in this global economy.

> America's core corporation no longer plans and implements the production of a large volume of goods and services; it no longer owns or invests in a vast array of factories, machinery, laboratories, warehouses, and other tangible assets; it no longer employs armies of production workers and middle-level managers; it no longer serves as a gateway to the American middle class. In fact, the core corporation is no longer American. It is, increasingly, a facade, behind which teems an array of decentralized groups and subgroups continuously contracting with similarly diffuse working units all over the world (p.81).

Another change impacting organizations and the polytechnics is that associated with work design. Most organizations and their technical staff and management (as has been with most technical faculty at the polytechnics) have been conditioned throughout their careers to the system of mass manufacturing pioneered during the early 1900s and commonly known as the 'Taylor methods of work organization.' The premise is simple: break complex jobs into a myriad of simple rote tasks, which the worker repeats with machine-like efficiency. Not surprisingly, this process is similar to the undergraduate education offered by the polytechnics today. Further it was believed that mass production methods would produce high volume, inexpensive goods and services for a long time to come (Taylor, 1967). However, individual as well as multi-conglomerates consumers are now demanding more for their dollar locally and world-wide.

These new consumers seek quality, variety and responsiveness to their changing tastes and needs. The new high performance forms of work organization today and tomorrow as represented by this paradigm shift, will operate very differently than the former and current Taylor methods. Rather than increasing bureaucracy, they attempt to reduce it by giving front-line workers more responsibility. Workers are asked to use more judgment and to make local decisions affecting their responsibilities. Developing breakthrough strategies that result in radical change to the work processes are becoming more typical with those organizations wishing to be more competitive and innovative. Mike Hammer, a leading national consultant on work design strategies, writes...

> When a process is reengineered, jobs evolve from narrow and task-oriented to multidimensional. People who once did as they were instructed now make choices and decisions on their own instead. Assembly-line work disappears. Functional departments lose their reason for being. Managers stop acting like supervisors and behave more like coaches. Workers focus more on the customers' needs and less on their bosses'. Attitudes and values change in response to new incentives. Practically every aspect of the organization is transformed, often beyond recognition (Hammer and Champy, 1993, p.65).

As a consequence of these Reengineering approaches to work design, management layers disappear as more front-line workers assume responsibility for many of the tasks, from quality control to production scheduling that others used to do (National Center on Education and the Economy, 1990; Austin & Gamson, 1983). In an article from the New York Times of Sunday June 7, 1991, "The Coming Crises of the American Workforce," Steven Greenhouse notes that as management removes more layers of bureaucracy and passes on more responsibility to lower levels, workers will have to be more adept at solving problems and communicating to others in and out of their discipline.

Robert Kuttner (1992), in his article titled "Working Smart," discusses the need for alternative work strategies to breaking jobs down to just simple tasks. In addition to calling for more investment in education, Kuttner urges state education policy makers to resist programs for pure vocationalism and producing just competent drones. He goes on to say that " the economy as a whole needs highly skilled, well-educated, and autonomous workers - the new technology requires it and global competitiveness demands it. Working cheap is static; a low-quality workforce doesn't make productivity gains, and it is increasingly out of step with the smart capital that is the real source of a wealthier economy over time (p.15)."

Several studies have been published that describe the expected needs of the future workforce.

In their report titled, How the United States Can Compete in the World Marketplace (Doyle, 1991), the Institute of Electrical and Electronics Engineers (IEEE) cautions its members that although U.S. engineering schools have been able to attract excellent students in the past, the decline in standards in public education and the lack of interest by high school graduates to pursue mathematics and technical careers will jeopardize future advances in their industries. They also note that during the past 50 years, as technology has grown more complex, the undergraduate engineering curriculum has continued to concentrate more on engineering theory than practice. As a result, these narrowly specialized engineering graduates have been oriented toward advanced R&D projects, rather than manufacturing applications, systems engineering, or product design in multidisciplinary team efforts. With decreased dollars by government and industry for basic and applied research, these graduates will be required to seek positions for which they are not prepared.

Based on the Bureau of Labor's statistics, the American Society for Engineering Societies (1991) and the Commission on Professionals in Science and Technology (1994) have noted that they find that there will be slower growth in the economy, and that higher skills will be needed in the workforce of 2005. These reports also noted that those occupations requiring the higher skills will also be the fastest growing. Also predicted by the US Government is that most of the jobs in 2005 in engineering will come from a replacement not an expansion of positions (Commission on Professionals in Science and Technology, 1992).

The study, Workforce 2000, notes that of the fastest growing jobs in the next decade, half will require a college level education and more than half will require education beyond high school. The report goes on to note that if every child who reaches the age of 17 between now and the year 2000 could read sophisticated materials, write clearly, speak articulately, and solve complex problems requiring algebra and statistics, the American economy could easily approach or exceed the 4% growth of the boom scenario (Johnston & Packer, 1987, p.116).

In the MIT study titled, Made in America (Dertouzos, Lester, and Solour, 1989) an emphasis is placed on broadening the skills of future workers that would enable them to make large contributions to the productivity of the firms and also to go on throughout their career in acquiring new skills. The report describes current technical education as too narrow and specialized, and that technical professionals have little understanding of the total production system. In describing the best practicing firms, the study identified a series of key factors. These firms had policies on human resources that promoted continuous learning, team work, participation and flexibility. These firms also hired individuals who had a wide range of problem-solving, team work and negotiation skills and experiences. The study also went on to characterize on the job training and education as compared to other industrialized nations and expressed a need for continuous learning on the job so that retraining can be a normal part of work life.

Preparing The Future Workforce

As a result of these many changes, the preparation and education for the technical workforce in the next decade will be greatly shaped by several influences. At the pre and post-secondary school levels, performance expectations and standards for education and entry into industry will be set by other industrial and emerging countries as they continue to compete world-wide.

The United States can no longer afford to be internationally the 16th and 18th respectfully with its high school graduates in mathematics and science skills or only recognized for the quality of its graduate programs (Vetter, 1991). As the information economy grows world-wide, there will be intense competition for a technically qualified workforce as opposed to the cheapest labor market. The supply of technically educated people for the workforce will need to be a priority of this country's citizenry and business as it is already with developing countries (Pickert, 1992). Organizations will continue to expect more from the individuals that they hire to do more than a single item or to solve more than simple or repetitive problems. In the future, the new practice of creating flexible job descriptions will require that employees have the characteristics of a specialist and generalist in the technical workforce. As continuous improvement has now become a minimum expectation of organizations today, continuous learning and training will be also required of the workforce to adapt to new approaches to problem-solving and technological changes. Undergraduate education will no longer be the end of a person's educational career but will be continuously augmented with on-the-job training, state-of-the-art workshops as well as the more traditional graduate programs and certificates.

Other influences shaping the future workforce will include the fact that companies are beginning to empower people, emphasize team work and collaboration, and require individuals to make more local decisions about the work for which they are accountable. Technology and a firm's clientele will demand that people work more efficiently and productively. Individuals will also need to direct their organizations to continuously improve the quality of the firm's products and services to exceed customers' expectations. The workforce must be prepared to look at and understand the larger picture that will make their firms successful in the long term.

Greater cooperation and linkage between industry and the polytechnics will need to occur to develop the lifelong learning skills, technical competencies, organizational, and behavioral skills over the career life of the employee. The current relationship of the polytechnics as just a supplier of new employees to the technical workforce is no longer acceptable. A new relationship of continuing education, in and out of the classroom, must be developed.

There are several consequences of this shifting work paradigm at the polytechnics. Appropriate student skill development at the undergraduate level requires redefinition. The polytechnics will need to go beyond the minimum accreditation requirements of technical competencies to include behavioral skills and an understanding of the world in which technology is utilized. The curricular structure and pedagogy requires a shift in emphasis from a specialization focus to include the impact on social and marketing concerns. Looking only at the technical solution without an understanding of the market forces will only lead to incomplete and partial solutions. New relationships need to be fostered with the professionals and industry that include a shared responsibility for the continuing development of a flexible and qualified workforce. Finally, a redefinition and accountability for faculty professional development and contact with the industries and professions for which they are developing future practitioners is a mandate.

Future Skill Development For The Technical Workforce

These consequences will in turn have an impact on the focus of skill development at the polytechnics. Currently, the polytechnics focus on three major skill areas at the undergraduate level. They are (1) the technical competencies that are needed to understand appropriate theory, context and applications within a specific discipline, (2) the professional competencies that are needed to function in the industries and professions such as obtaining appropriate registration or certification in one's field of study, and (3), continuing learning competencies for further education in one's discipline including graduate programs (Enst, 1993). Although previously appropriate when industry was organized and utilized a division of labor model that created discrete operational and segmented units, these forms are no longer adequate today for the many changes that continued to go on in business and the economy.

Emerging from the paradigm shift in work design, are five new major competencies that will be needed at the polytechnics to redefine a graduate's skills and development at the undergraduate level. (1) An expansion of the learning skills for lifelong scholarship and professional development, self-confidence, communication, critical thinking and synthesis, flexibility in preparing for career changes, and adaptability on the job to technological, economic, and organizational changes. (2) The development of technical, innovative, and context skills for understanding and applying known theoretical knowledge and experiential processes to technical problems within the larger issues of society and the marketplace. (3) Creating an awareness for organizational and interpersonal skills for developing behavioral, decision-making, and leadership attributes needed to creatively participate within groups and to take advantage of the diversity of skills and opinions that others bring to an interdisciplinary and collaborative process of solving complex technical and social problems. (4) Marketing skills for understanding the issues of product and service quality, business competition and meeting the needs of the client. (5) A common set of ethical and value standards to address the social, economic, and political questions related to the use of technology in solving societal problems (Lynton, 1991, Moody, 1993, and Schön, 1987).

As corporate structures become leaner and more horizontal, there has been an increased emphasis on team work, on close collaboration among design, manufacturing and sales personnel, and on the direct contact of technical expertise with external clients (Champy, 1995 and Peters, 1988). As a consequence of these changes, individuals in many different settings have to assume greater responsibility, participate more directly in decision-making, interact with a broader variety of colleagues and clients. As a result, they must be more than narrow specialists. The content of the career-oriented major itself must be expanded so as to allow students to acquire the necessary understanding of the context in which they will function as practitioners, and of the ethical and legal issues which they will confront. The approach to this broadening should be one of assessing the technology, focusing on the societal and organizational impact of the new technologies, on their positive potential and their downside risks, and on various ways in which they can be used. The purpose of such courses should be to enable individuals to assess the impact of external factors on their work beyond their own area of specialization and not to make them mini-experts (Lynton, 1982).

For the polytechnics, this means that the emphasis on learning skills in the curriculum should be to expand a graduate's potential after completing the prerequisite courses and not just on an ability to succeed while in college. Collaboration among the technical and liberal arts faculties will be critical in developing a program of study that enables students to acquire the confidence levels to take risks while advancing in their careers and to make the necessary compromises that are part of one's professional and personal life (Lynton and Elman, 1987). An attitude must be developed in the polytechnics as well as in industry that most of the technical learning is actually done on the job and throughout one's career. Learning skills must be able to address these needs.

This also puts greater pressure on the schools that are admitting students today. They must first focus on some remedial training. But remedial work cannot be a substitute for the other learning skills needed later in one's career and life. Communication competencies require that the graduate can read, write, speak, and listen to acquire, develop, and convey ideas and information. Critical thinking skills need to examine issues rationally, logically, and coherently. Further, these thinking skills need to allow students and graduates to develop a repertoire of thinking strategies that will enable them to acquire, evaluate and synthesize information and knowledge.

As organizations redesign work processes to be more competitive, so must the polytechnics with its curricular structure and pedagogy to better prepare its students. Donald Schon in his book, The Reflective Practitioner (1983), points out that the complexity and messiness of reality carry fundamental implications for the nature of expertise and the competence of the practitioner. Broadening the content and range of expertise is not sufficient. The real change is in the way of knowing, in the 'epistemology of practice,' and in the habits of mind. Schon points out that real problems are rarely defined, available data is usually not sufficient for rigorous analysis, and that there are no unique solutions to any given problem. Critical thinking and other aspects of higher-order reasoning are clear elements of professional competence. The education of the future practitioner must help them recognize many different factors which affect a given situation, discover the real problems "out there," identify available options and the tradeoffs involved in each, recognize the limits of what can be accomplished, and finally make choices and compromises. Such skills, all components of effective critical thinking, cannot be acquired in an abstract fashion. Content and process cannot be separated. Teaching new ways of approaching complex problems must be directly related to the appropriate area of professional activity.

A consequence of the experiential learning model previously described in Chapter One, will be that the curricula, pedagogy, and "practical experiences (such as internships and cooperative work terms) should begin early in the curriculum and be used as a primary learning experience from which generalizations are drawn inductively not only in the practicum itself, but also through the concurrent and subsequent classroom work (Lynton and Elman, 1987, p.15)." Specifically, the loose connection of courses to meet accreditation standards, registration and certification standards and exams, and prepare students for graduate work must all be re-examined. A set of performance criteria based on the necessary skill developments previously mentioned must be established. Then courses can be designed to bring a logical progression of these developments through the years of study. Additionally, opportunities in the curriculum need to be established to assist students in understanding the processes and their limitations.

Another consequence of this paradigm shift in work design will be in the relationships between the professional societies, industry and the polytechnics. New expectations from the professions will need to be translated into educational criteria and how the polytechnics will be evaluated in the future. In the past, donations of money for scholarships, faculty chairs, facilities and equipment were given to help educate the novice. In the future, opportunities for faculty to upgrade their skills in this new work environment may be even more important. Special programs will also be required to assist professionals and the technical workforce who are caught in a transitional period so that they may again renew their level of productivity. Regarding the apprenticeships required for registration, most firms leave it to the apprentice to seek out the best experiences and are as helpful as they can be in placing the recent graduate in a variety of experiences. The point of view for both firms and individuals is that the relationship is focused on individuals gaining responsibility and challenges throughout their career and the firms hiring people as needed. As this changes, there will be a need for a greater sharing of responsibility for the development of the technical workforce, not only with individuals but also with the schools and the firms.

In the countries of Germany and France, there is already a dual responsibility between industry and government for the development of the workforce (Jonen and Roche, 1982, Magaziner, 1992, and Timmermann, 1991). This is also true in Japan (Pickert, 1992). This dual responsibility also includes the sharing of the educational and training costs when the individual makes a commitment to work for either an industry or specific firm. In the United States, the prevailing attitude for employees to pay for their own continuing education that also could benefit the firm is beginning to change. More recently, NYNEX negotiated a contract with their crafts people to pay one day a week for employees to go back to college to complete programs in technology. In addition to paying all educational costs, NYNEX had also decided to pay for that day away from their work. This is an example of the employer investing in the human resources of the firm in conjunction with the polytechnics to develop the existing workforce that is already in place. Other organization in this country, if they are to remain competitive, will need to collaborate with the polytechnic education as a necessary step in the development of their workforce. By doing so, the firms will also be able to assist the polytechnics in continuing to attract a sufficient number of qualified applicants from high school to study the disciplines in science, engineering, and technology and be a partner with higher education in developing the future technical workforce in this nation.

As in these other industrialized countries, polytechnic education must be seen not only as a starting point but also as a place to return to continue with a career path and to confront change in the workplace. As such, US firms must also begin to take on a larger responsibility and costs for developing that workforce now that they need to be globally competitive. Additionally, government policy must be reviewed to encourage private enterprise to invest in human resources of this country and to assist in the recruitment, training and education, and employment of a highly skilled workforce. Time must also be given to employees to retrain as industry anticipates changes in the marketplace. In France and Germany, those industries or firms not currently participating are taxed to supplement funds for the workforce.

As is with a school of higher learning, the quality of the faculty is critical. Professional development at the polytechnics already includes opportunities to participate in professional societies, consulting, credentials, and teaching methodologies. Most of this activity is part-time and of occasional value at the undergraduate level. Since most of the technical faculty have come from industry and rely on the techniques of their profession for teaching in the classroom, opportunities must be developed to allow faculty to return to practice periodically to also gain the experience of the organizational changes. As important as it is for the practitioner to return to formal training and education, the same argument can be made for the technical faculty to return to full-time practice and to bring that new experience back to the classroom. Additionally, pedagogy that invites practitioners to review student work such as on projects and studio work must be investigated. Challenging students to examine their current thinking patterns and biases is also essential.

A skills gap for the undergraduates at the polytechnics has been created by the forces of change in the workplace. Some of this has been through the introduction of new technologies, but much of it is the result of organizational change, new demands placed on people to work smarter and more productively, and the need of organizations to compete globally. The next chapter will discuss the gap that has been created by the current level of preparation skills of those undergraduates coming to the polytechnics today and by those projected in the future.

CHAPTER 3

THE POLYTECHNIC STUDENT

In the last two decades the number of academically qualified students seeking an education at the polytechnics has declined. This chapter will describe some of the reasons for this decline in academic preparation for study at the polytechnics and impact on its form of education. Included in this chapter will be a discussion of the factors expected to shape the college preparatory skills and educational objectives of future polytechnic students.

In 1987, the National Science Foundation completed a study of high school sophomores in this country who went on to study in the college disciplines of science, engineering, and technology (Tobias, 1990). The population used for this study was 4 million sophomore students who expressed an interest in taking mathematics. For several years, the level of achievement in high school mathematics was a key indicator in determining who would pursue a career in science, engineering, or technology after high school graduation. Eighteen percent (18%) of high school sophomores in 1977 expressed an interest in engineering, technology, and science and were taking the expected mathematics courses in geometry, algebra and trigonometry. By the end of their senior year, the interest of this cohort had dropped to 14%. Eight percent (8%) of these graduating seniors actually enrolled in basic science and polytechnic (engineering and technology) programs. Only 5% of those graduating high school seniors who began a college program in science, technology, or engineering graduated in 1984, which is 5-7% less than the high school graduation rate in other industrialized countries (Cheney, 1991). As a result of the demand and low supply of a technically educated workforce, the polytechnics experienced a peak of student enrollments in the 1980s. Since then, there has been a steady decline of about 5% per year of new students entering the polytechnics. In addition to the decline in actual numbers of new entering students, there are now many more students being admitted into college who are less-than-prepared for this type of education (Astin, Koran and Riggs, 1993, College Boards, 1993, Futrell, 1993, and National Center for Educational Statistics, 1994).

As entering enrollments began to decline in the mid-1980's, the polytechnics were beginning to observe an increase in the number of first-year students requiring remedial coursework in mathematics, writing, and study skills (Brodsky, 1991, Fidler and Fidler, 1991, Greenhouse, 1991, and Luker, 1990). Alarmed by this situation, accrediting, government and professional societies called on the polytechnics to tighten their admission standards in order to minimize the impact of the less-than-qualified high school graduates going into college. Despite these calls to limit enrollments, the polytechnics focused their attention solely on developing marketing strategies to counter a diminishing pool of high school graduates for their programs and to maintain their existing student populations. With years of higher student attrition, that attitude has now begun to change at the polytechnics (National Science Board, 1992, Okyere, 1991, and Schmitt, Bement, Baker, Cotton, and Drucker, 1992).

Faced with the possibility of canceling courses and programs in the 1990's, the polytechnics began to discuss approaches to retain more of their students in addition to how to attract non-traditional students into their programs. Faculty and administrators are now trying to find answers to some of the following difficult questions.

1. What will be the <u>motivation</u> of the future high school graduate to pursue an undergraduate degree at the polytechnics?
2. What can the polytechnics expect in regard to <u>college preparatory skills of the future</u>?
3. In what other ways will the incoming students be <u>different from those of the past</u>?
4. Why are <u>fewer qualified</u> students being attracted to the polytechnics?

The Good Old Days

At the polytechnics, as is the practice in related technical industries, it is not uncommon to establish measurable criteria or "bench marks" to current systems and processes or with results from competitors that an organization is attempting to emulate. For example, when Ford Motor Company decided to improve its accounts payable systems (e.g. paying the suppliers for goods and services received) they used Nissan Corporation, a competitor and recognized leader in having good working relationships with their suppliers, as a "bench-mark". For approximately the same volume of receivables, Nissan had a system that utilized four (4) people to pay suppliers. Ford Motor Company had a system that required four hundred (400) people (Peters, 1988)

The "bench mark" used by faculty for today's entering classes at many polytechnics has been the admission standards that were used when they applied to the polytechnics during the 60s and 70s. Typically, the admission standards during the 60s and 70s expected public high school students who entered engineering and technology programs to be prepared for college-level algebra, trigonometry, pre-calculus and physics (American Society of Engineering Education, 1987). The applicants were students who were academically competitive and typically from the top twenty-percent of their high school class, had achieved a combined Scholastic Aptitude Test (SAT) scores greater than 1100 (College Boards, 1993 and Viggiano, 1993), enjoyed dismantling “mechanical and electrical objects” to figure out how they worked, and had decided that they were interested in a career in engineering or technology by the ninth grade.

In the early 60s there were a number of resources, including equipment and teacher development, provided to the local high schools when the United States Government attempted to close the scientific and technological gap created by the launching of an artificial satellite, Sputnik, by the Soviet Union. During the mid-sixties, this emphasis and support for high school mathematics and sciences expanded as the United States became a willing participant in a “race to the moon.” High schools were frequently visited by engineering and scientific guest lecturers from industry and students were invited to visit local industries. Science fairs were popular examples of how mathematics and science teachers attempted to encourage interest and learning in their school systems. Generally, all students were required to participate in these annual events. Many states supported the science fairs with awards and scholarships so that those interested high school graduates could continue with their studies in science, technology, or engineering. New and emerging technologies and consumer products such as electronic miniaturization (the transistor radio and calculator), materials from “space” (cookware and fabrics) and chemistry (instant photography and plastics) captured the imagination of many potential students.

The traditional mix of students entering the polytechnics during the 1960s and 70s was 17- and 18-year old white males (90% of the entering class) who had acquired a “work ethic” from their parents and high school teachers

(Magaziner, 1992, National Center for Educational Statisitics, 1991, and Tobias, 1990). They were challenged by difficult problems, and were eager to learn. For the better students, merit scholarships and other forms of grants, such as the National Defense Loan, became available to fund study at the polytechnics.

With increased research support from the government came new funding to the high schools and the polytechnics for studies in mathematics and the sciences. At the polytechnic undergraduate level, improvement of facilities and equipment, recruitment and development of staff and faculty, and other forms of student financial aid, such as work-study for those in science, engineering and technology, became available and then expanded to serve more students. This was a period when the goals of the students in the polytechnics, their families, the society, politics, and the economy were in harmony.

As a result of this combination of support, the majority of students who were selected by the polytechnics had taken high school courses and programs designed to prepare them for college-level work. They were encouraged to be self-directed and to work hard. Initially, because many students had already competed to enter these programs (there were fewer seats than students applying), they remained very competitive and academically aggressive in the classroom. Students knew that there was much demand to fill the few classroom seats available. Typically, the polytechnic students of the 1960s and 70s were students who averaged 100 or more points higher than the national average on the mathematics SAT section and about 50 points higher than the national average on their verbal SAT section (National Commission on Excellence in Education, 1983, National Science Board, 1986 and Stoin, 1994). Entrance to a majority of polytechnics in the 1960s and 70s also required knowledge of a foreign language and more than one science while in high school (usually physics, chemistry and biology). Students typically had four years of mathematics in high school including algebra, geometry and trigonometry. For students who did not meet these qualifications, two-year associate degree programs were available to develop the necessary learning skills and experiences to transfer into an engineering or technology baccalaureate program (American Society for Engineering Education, 1986).

Changing Realities

When establishing a “bench mark” to evaluate the level of preparedness of today’s students, it is important to remember that most of the polytechnic faculty today are either the products of this educational system or were involved in it as young practitioners or educators in the 1960s or 70s. Much has changed in the twenty or thirty years since the current polytechnic faculty received their education and practical experience. For the most part, although course content has been updated, faculty expectations and pedagogy have not adapted to the new student cohorts who are now seeking a career at the polytechnics.

In addition to lifestyle changes influencing today’s students, changing educational and career expectations by their families and the society as a whole have greatly impacted the number and attitude of new students coming to the polytechnics. A special assessment conducted by the National Assessment of Educational Programs verified a direct relationship between high achievement and high economic status, high level of parental education, low absenteeism, and low levels of television-watching (Astone and McLanahan, 1991). The growth of poverty has been disproportionate among families with school-age children in this country (1 in 4 children are now considered at the poverty level - Futrell, 1993). This poverty places the educational development of 25% of the nation's children in jeopardy. Many now come from urban areas with high unemployment. The "latch-key" child trend among middle-income families is also on the rise as affordable day care is less available. Based on recent changes in family structure, including the increase of single parent and stepparent families, have shown that children from these families are less likely to complete high school or attend college as compared to the traditional two-parent families (Astone and McLanchan, 1991, Futrell, 1993, and Marsh, 1990). Although many of the polytechnic graduates from the 60s and 70s came from a lower socioeconomic status, they were able to afford a polytechnic education because job opportunities were increasing and government financial aid support was greater.

The following two examples demonstrate changing expectations impacting the polytechnics. The effort required to acquire an education at the polytechnics is viewed as taking too long (5 years for a 4-year degree), too difficult (an average of 20-plus hours in class and lab periods), and being too expensive when compared to tuition costs and the amount of student loans needed to complete a baccalaureate program in business versus science, engineering or technology (National Center on Education and the Economy, 1990). The current economic uncertainty and the downsizing of engineering, technology and manufacturing firms has also contributed to the lack of interest by students in the type of education provided by the polytechnics (National Science Board, 1993 and Tobias, 1990).

With many more companies moving their manufacturing processes to "Third World" countries, the need for service industry and financial skills has increased. Technology is no longer seen as an answer to improve economic or societal concerns, but is now seen in many cases as the problem that must be solved such as the technological consequences related to environmental (waste, water quality), pharmaceutical and the health care industries. Today, there are more non-technical people in government and industry, including lawyers and business administrators involved in technical policy-making, than those who were educated in science, engineering or technology (National Science Board, 1992 and Reich, 1992). Public opinion, government regulations and deregulation of some industries, and the loss of positions have contributed to the diminished enthusiasm for those who might have otherwise considered a career in science, engineering or technology.

Today, with the high cost of education, students are looking for career opportunities, mobility and transferable skills that will allow them to obtain adequate compensation and a chance for advancement. The efforts needed to develop the necessary skills in mathematics and the sciences are not seen by the student as "value-added" to their lifelong educational and career objectives. The cyclical effects of the economy on scientific and technical organizations such as those on Route 128 (Massachusetts' Technology Highway) or Silicon Valley (California's computer chip industry) also reinforce a perception by parents and students that the effort to obtain a technical education, when understood in terms of job security and compensation after graduation, is too risky. High school teachers in mathematics and science had traditionally served as the role models and advocates for encouraging students and their families to continue on with their studies in mathematics and the sciences. But with fewer mathematically and scientifically educated post-secondary educators (today few high school teachers have an undergraduate degree in the discipline that they teach) there has been a loss in the number of mentors to guide students in making educational and career decisions involving science, engineering or technology.

The fact that there are fewer post-secondary school teachers educationally qualified in mathematics and sciences and little commitment or support in the high school systems to strengthen the graduation requirements in mathematics and sciences, have each combined to provide a less-rigorous curricular content in these subjects. Along with the many other "lifestyle" changes in our society, college-level preparation at the high schools has diminished. Collectively, these changes have negatively impacted the motivation and academic preparation of students interested in pursuing an education in science, engineering and technology (Commission on Professionals in Science & Technology, 1992, National Center on Education and the Economy, 1990, and National Science Board, 1992 Commission on Professionals in Science & Technology).

There have been a number of studies to determine the problems associated with students and their level of preparation for the science, technology and engineering disciplines. Chief among the problems that inhibit development of skills and competencies in mathematics and sciences are: 1) lack of parental encouragement, 2) diminished parental resources including involvement in their children's career objectives and study habits, 3) reduced expectations by teachers and parents for student performance, 4) teacher quality - too many teachers are being recruited from the bottom quarter of graduates from high school and college students, 5) gender bias - where female students are discouraged to take mathematics and sciences by parents, teachers and counselors while in high school, 6) lack of persistence in taking and completing mathematics at an early age, and 7) an inadequate amount of homework. These concerns also affect other learning skills and attitudes of future high school graduates coming to the polytechnics (Vetter, 1991, Cheney, 1991, Ellis and Buffee, 1993).

The report, A Nation At Risk (National center on Excellence in Education, 1983), records the decline of the American educational system. High school graduates of the eighties should have been the benefactors of the educational reforms made during the 1960s and 70s. National assessment tests and other devices, such as Scholastic Aptitude Tests, tracked a nation of students whose overall scores declined for more than ten years (Carnegie Commission on Science, Technology and Government, 1992, Cheney, 1991, and Commission on Professionals in Scienceand technology, 1992, and Fetz and Catania, 1992). The educational reforms designed to improve the high school resources of facilities, equipment, curricula and faculty were not effective. The changes in family structure, socioeconomic decline, demographic changes, shifts in societal values, and indifference or distrust towards established institutions, such as education and higher education in particular, created a difficult learning environment. In addition, these changes led to decreased resources and a lowering of expectations by parents, secondary school teachers, administrators, and the students themselves.

> Present precollege education in science and mathematics overall, is uninspired, and all too often inadequate even for those whose enthusiasm for science and technology is not squelched by uninteresting classes. As a result, the level of scientific literacy among Americans is distressingly low (Vetter, 1991,p.17).

As a result of inadequate teaching of mathematics and sciences in the United States, only 37% of high school graduates have taken chemistry, 18% have taken physics, and only one-half of all high school graduates have taken up to 9th grade mathematics (Merante and Ireland, 1993). The majority of those students choosing an education at the polytechnics, will have had mathematics or science high school teachers who did not major in these fields but who have only taken a few courses themselves (Weiss, 1985, Astone and McLanahan, 1991). The amount of homework has significantly decreased in the public high schools. Two-thirds of public high schools report that less than one hour of homework is given per school night (Andersson and Young, 1992 and Vetter, 1991). Based on national tests given today, nearly 40% of 17-year old students can not draw inferences from written material, only 1/5 can write a persuasive essay, and only 1/5 can solve mathematical problems requiring several steps (National Research Center, 1993). Most polytechnics have dropped their previous foreign language requirement. Compared to other industrialized nations, US. high school students are in class two hours less per day (six hours versus eight hours) and a total of 40 days less per year (180 days per year versus 220 days - Cheney, 1991). Studies by the American Council for Education also show that a smaller percentage of the United States' "better" students, who were inclined to seek a career in science, engineering or technology in the past, are now gravitating to programs in business and law (Anderson, Carter and Malizio, 1992).

The time for watching television or playing video games far exceeds the time spent by students today in reading and doing homework assignments. In addition to fewer mentors and teachers advocating the taking of mathematics and the sciences, stereotypical thinking by parents, teachers and counselors continues to create roadblocks for women and minorities in the seventh and eighth grades to taking mathematics. This is preventing a whole generation of non-traditional students from exploring the opportunities in an age of high technology.

With reduced homework and expectation by the high school teachers for their students' academic preparation has, in part, created the need for the polytechnic students to take more remedial mathematics, reading, and writing courses. By offering more of these remedial courses, students and faculty hoped that 12 years of problems could be corrected in a semester or two. Numerous studies conducted over the past ten years on entering college students, indicate that they do not have adequate preparation in study, cognitive, writing, reading, mathematical and critical thinking skills to participate in college today (ASEE, 1987, Cheney, 1991, and National Science Board, 1986). Today, a typical complaint of faculty is that students are coming to class to be lectured (or entertained) and are not there to learn on their own (Tobias, 1991). Students being admitted into the polytechnics are now the "C plus/B minus or above" high school students with an average 950 combined SAT score of which the mathematics scores approximate 500 (Anderson, Carter and Malizio, 1992 and College Board Report, 1990). These scores show that students in the 1990s on average scored lower than students who took the examinations during the 1960s whose average scores were 1100 (ASEE, 1987).

In general, today's 13-year old student knows less mathematics and science than his contemporaries almost anywhere in the world. Fourteen-year old students have mastered no more than basic arithmetic. "Less than 1/2 of our eighth graders could tell the weight of a 30-pound object when it was taken to the moon, after being told that the moon's gravitational pull was 1/6 of that on earth (Vetter, 1991, p. 39)." One-half of the 12th graders in 1991 scored below the expected level of understanding for 8th graders in mathematics, science and in solving word-problems. Only one student out of twenty scored at a level where they could be described as "equipped to do college work in algebra and geometry" (Cheney, 1991, p. 62).

The demographics of the entering classes in 1991 were still predominately white males of about 18-years old (60%) although many of the polytechnics are now admitting more international (10%) and twenty-one year old college transfer students (15%) than ever before (ASEE, 1994). A major factor for this change was the level of academic preparation and reduced numbers of graduates from the public high schools. Women now compose about (15%) of the polytechnic programs' population. In the year 2000, it is being projected that 85% of new entrants to this nation's workforce will be members of a minority group or women (National Center for Education Statistics, 1991).

The continuing concern over the lack of academic preparation has been a focused concern by the accreditation groups as well as the professional societies. The students have weak study skills (time management, note taking), and are lacking the cognitive skills that were taken for granted by faculty in prior years. With increased pressure to pay for their education, many more students are working beyond the 15 hours per week recommended by most colleges (Astin, Korn and Riggs, 1993 and Boyer, 1993). This, of course, leaves less time to study and pursue other interests in their discipline such as participating with professional society chapters on campus. It now takes a student who is enrolled in his or her four-year program about 5.1 years to complete an undergraduate program (Anderson, Carter, and Malizio, 1992, ASEE, 1994, and Ellis and Buffee, 1992). This extension of time to graduate is a result of numerous factors including students' needs to repeat required courses, and take reduced loads in order to work and finance their education.

A New Bench Mark

For those students presently in the 7th grade and above, educational reform will have no measurable impact on their preparation for college. The National Center for Educational Statisitics' assessment of testing programs showed that 9th graders in 1991 had improved their scores in mathematics and sciences compared to the 1973 level. However, these results were still much lower than the 1969 test results. Despite these numerical gains, however, student proficiency, had only occurred in the lower level skills for understanding the application of basic mathematics and sciences. Student performance in the areas of complex problem solving and the use of multiple variables had actually decreased. This means that the learning skills and experiences of students entering the polytechnics between 1993 and 1998 will be approximately the same as they were for the students entering between 1985 and 1991 (Commission on Professionals in Science and Technology, 1992, National center for Educational Statistics, 1994, and Viggiano, 1993). Based on demographic information, the mix of students presently coming to the polytechnics in the early 1990s will be approximately the same as those students now being attracted primarily from the suburban communities.

For those students presently in grades one through six, efforts to improve mathematics and science learning skills and literacy could have a positive and measurable impact on their college preparatory skills if it was at all possible to immediately improve the current educational system overall and the quality of mathematical and scientific instruction in particular. However, if improvements to correct those areas most commonly cited as reasons for poor mathematics and science student skills results, such as poor teaching, prevailing myths and biases towards women and minorities taking these subjects, a lack of parental support and role models, increased use of homework and better textbooks, do not occur within the next four years, then the entering polytechnic student in the year 2005 will be no better prepared than today's student (Barton andLapointe, 1995, Futrell, 1993, Greenberg, 1991, National Commission on Excellence in Education, 1983, National Research Council, 1993, Schreiner, 1988, and Vetter, 1991). "High-tech" solutions, such as the use of computer-aided instruction, can be helpful but only in combination with these other improvements.

Given that most grade school and high school teachers now employed have seniority and that a high turnover rate of existing teachers is not expected in the very near future, the quality of secondary teaching in mathematics and science courses will not greatly change and improve in this decade. Despite calls for reform, the focus of government spending over the next decade in secondary education will be on "getting students ready to learn," techniques for students to finance increasing higher education costs, improving teachers' education, and providing opportunities to improve adult literacy, complete high school graduation requirements, and for on-the-job training. Efforts to improve the current system of secondary education will continue to be fragmented with the responsibility placed on local groups of concerned citizens, parents and businesses.

Despite this prognosis, there are groups who are attempting to make a difference at the post-secondary level. For example, professional societies, have begun to increase their support, such as the National Society of Professional Engineers (NSPE), with its national program called "Math-Counts." This program is designed to encourage students to continue with their mathematics and sciences while in high school. Non-traditional students in science and engineering, such as women and minorities, who do not presently take mathematics or science beyond arithmetic or an introduction to science, are currently being targeted by the professional societies and the "high-tech" industries for additional support and encouragement. Articulation agreements, like the federally-funded Tech-Prep program, have been designed to encourage faculty from the colleges and high schools to coordinate curricular content so as to encourage students to seek application to local colleges with the possibility of advanced standing credit from their high school. It is believed that these relationships will strengthen the quality of instruction at the high school level while at the same time directing students into the technical disciplines.

Articulation agreements with area colleges and high schools will also be increasing to allow for some additional collaboration in the classroom, especially in urban areas. Major industries, such as those in the computer and energy technologies, have expanded their educational assistance programs to help provide high school instruction in mathematics and sciences. Although fragmented, some of these and other efforts are beginning to indicate some hope that the quality of instruction in high school mathematics and science courses can be improved over the long term. This should also encourage more students to take these courses and possibly think of careers in these fields as well. With greater assistance from industry, more of these students will be part-time students who will be paid by their employer to take courses and to work at the same time.

In addition to these attempts, national organizations of mathematics and science teachers have prepared and disseminated new standards in their fields as well as suggesting improvements to the pedagogy to attract and retain more students. Educational models presently being used in Europe and Japan are now being discussed among US. educators, government representatives and industry to improve broader literacy in mathematics and sciences.

Student Profile

The class of 2005 is now in the first grade. Without the improvements previously outlined, it is projected that only 73% of this group will receive a high school diploma and that less than 5% of these graduates will study sufficient mathematics and sciences to enter the polytechnics in the future (National Center for Educational Statistics [NCES], 1994). Although it is expected that women enrolled in college will be about 56% of all enrollments, the number of women in the polytechnics will not significantly change from what it is in 1993 (15%) unless recruitment efforts and the prevailing myths and biases by parents, educators and industry can be altered (Commission on Proofessionals in Science and Technology, 1992 and NCES, 1994). It should be noted that student retention statistics are above the norm for women at the polytechnics.

However, based on projected new industries that do not have "glass ceilings" for the current non-traditional student at the polytechnics (i.e., biotechnology, telecommunications, health care technologies), it is predicted that by the year 2005 the composition of the entering polytechnic class will be as follows: 50% white male, 25% women, 15% international, and 10% minorities. Fifteen-percent (15%) of this class should be students who went directly to work after high school graduation and 25% will be transfer students from non-technical fields.

The overall level of mathematics and science competency of high school students entering the polytechnics up through the year 2005 should not decrease any further. What this means, however, is that there will continue to be a large learning gap for students attempting to take the more traditional college entry-level mathematics and science courses. It is expected that reading and writing skills will not have improved from their present level. SAT scores will continue to decline, but will remain slightly higher at the polytechnics than the national averages (870 combined SAT scores with the higher scores still in mathematics). For many students, the first two years of college may need to be designed as a two-year extension of high school courses to focus on the necessary college level study and learning skills as well as the basic competency levels in mathematics, science, reading and writing.

New attitudes and adjustments will be needed by the faculty and polytechnics overall. In the year 2005, the challenge for the polytechnics will be to continue to attract students to the disciplines at an even earlier age (starting at grade 4) by working with the local elementary, vocational and high school faculty and administrators. New educational "bench-marks" for high school graduates are already being established by the international community, especially in those industrialized nations that compete economically with the United States. For example, competing nations require that their comparable high school students complete courses in mathematics and sciences that polytechnic students now take in their first two years of college. Expectations to succeed in the scientific and engineering disciplines by parents, educators and business leaders in the United States will need to match those from other countries. Developing attitudes towards life-long learning, language skills, and interpersonal skill development will need to be encouraged in grades K-12. These will need to become part of the new "bench marks" of the future. For now, mastering basic mathematical, scientific, communication, and learning skills will have to be the "bench mark" for many of the students graduating from public high schools and the polytechnics through the rest of this decade.

Chapter Four, Academic Bridges, will discuss the current and projected efforts to bridge the learning gap based on this new reality of academic preparation with high school graduates who are presently being admitted into the technical disciplines at the polytechnics.

CHAPTER 4

ACADEMIC BRIDGES

This chapter will describe and discuss the academic strategies and tactics presently used by the polytechnics to bridge the learning skills gap resulting from today's less-than-academically prepared high school student. In reviewing these strategies and tactics it was helpful to ask the question: is the motivation to establish "learning skills gap" bridges driven by enrollment management (recruitment and retention) or by the desire to educate quality graduates for America's technical work force? While this enrollment management attitude might seem cynical on the surface, it is still a far better perspective (although economically driven to help schools survive) than the previous academic attitude manifested in introductory remarks made by educators in the '60s and '70s to freshmen. Those freshmen were told to "look to your left, look to your right; less than half of you will complete this program of study." Educationally and economically, we have moved beyond this attitude.

The discussion of academic bridges in this chapter is divided into two parts. The first part is a review of the current strategies and tactics used by a number of polytechnics to bridge the gap between the academic preparation of entering students and the learning skills required at the polytechnics. The purpose of these strategies and tactics is to enable students to develop the necessary learning, behavioral, and technical competency skills required at graduation. The second part will take a closer look at one polytechnic (Wentworth Institute of Technology) that has used a number of these strategies and tactics to improve student recruitment, retention and learning. By focusing on one polytechnic, the collective impact of academic bridges on learning experiences and successes of students can be examined.

An Overview

Since the publication of A Nation at Risk in 1983, the polytechnics have known that the demographics and academic preparation of high school graduates would directly impact their collective ability to educate sufficient numbers of students in their disciplines. However, it was not until five years later, when student enrollments began to decline, that the polytechnics began to address the issues of academic preparation. Generally, the first reaction by many at the polytechnics toward the problems of increasing attrition was to introduce remedial courses into the curriculum. A second reaction was to offer pre-engineering or pre-technology programs to attract and academically prepare the applicant pool prior to being admitted to a degree program. By the early 1990's, more than 80% of colleges had introduced remedial courses in mathematics and English (Brodsky, 1991, andFedler, Forrest, Baker,-Ward, Dietz, and Mohr, 1993). For those admitted into degree programs, additional learning resources were provided in the form of peer tutoring programs, freshmen orientations, and a battery of placement testing instruments for the introductory English, mathematics and science courses. In an attempt to improve the number and academic preparation of future students, faculty, students, and alumni became much more involved in the general recruitment efforts at the polytechnics. However, these initial attempts to improve the pool of entering candidates and to help increase student retention were only marginally successful because they did not address the basic cultural values and educational traditions at the polytechnics that were directed at "weeding-out" students for the professions.

With increased pressure to survive, faculty, administrators and staff began to examine their educational environments by using some of the business school approaches to marketing to improve their own recruitment and retention efforts. Four new strategies began to emerge and gain acceptance in the late '80s and early '90s including: (1) creating an office of enrollment management (consolidating student recruitment and retention efforts) to accentuate the priority within their community; (2) adopting Total Quality Management techniques to improve student services and the delivery of classroom instruction; (3) an increased emphasis on recruiting non-traditional students including women, minorities, and transfer students from two-year colleges; and (4) program articulation and other educational agreements with high schools and technical vocational schools used to expedite transfer to a college after graduation that was based on additional academic preparation within existing secondary school courses. These were in addition to the various ongoing strategies of price discounting (scholarships that used institutional dollars), recruiting international students, and improved public relations (to get the "word" out about your college to the public, prospective applicants and their families).

At the same time these new initiatives were being developed and implemented at the polytechnics, a growing number of faculty also began to expand on the previous work of others regarding the effectiveness of student learning to teaching styles in order to improve student retention. This effort resulted in a critical examination and assessment of the learning experience by some in the technical disciplines to improve the quality of teaching at the undergraduate level. This in turn has forced the polytechnics to question the effectiveness of their pedagogy and curricular structure on student retention and preparation for the technical work force. As a result, an increased level of awareness and discussion of retention and academic preparation has been generated among the polytechnic colleagues at their professional meetings and on their campuses (Davis and Murrell, 1993 and Okyere, 1991). It has also expedited the work of the polytechnics in adopting new criteria to assess both student performance and the learning process.

It is important to understand these four academic bridges in more detail. We will begin by reviewing the areas of student recruitment, curricular modification, academic services, and pedagogy.

Bridge One - Recruitment

Like many colleges in the United States, the polytechnics have discovered a new set of realities that are dictating the methods they must use for recruiting students to their academic programs. The realities of this decade and the first decade of the 21st century for faculty and administrators are punctuated with paradoxes. Some of these are best illustrated by the changes in work design and production processes in the technical work force. This includes reduced personnel needs (discussed in Chapter Two), which have caused fewer positions for future graduates. Although high school graduates are projected to increase beginning in 1994, interest in the disciplines at the polytechnics continues to decline (Commission on Professionals in Science and Technology, 1994 and Engineering Workforce Commission, 1994). Academic preparation in mathematics, sciences, learning and study skills, personal motivation to follow through (persistence) and a personal standard of working hard and working smart (work ethic) also continue to be in decline. This decline is also disproportionately higher with minority students who are increasing in total numbers. The percentage of young women participating in high school mathematics and sciences has also remained level. To counteract these declining enrollments, diminishing academic preparation, and the increased competition among colleges, the polytechnics have developed two types of strategies related to this first bridge. [1]

Internal Coordination-Getting Your College's Act Together

With an increasing number of polytechnics embracing academic strategic planning techniques, as is oftentimes encouraged by regional and program accreditors, a series of internal coordinations among faculty, staff and administrators has developed. The traditional attitude that "admission will bring in the students and the faculty will screen them out" is being replaced by "a shared sense of economic reality, discussing academic strengths and weaknesses, and a collegial give-and-take on key issues" (Merante and Ireland, 1993, p.12). Discussions of market niches and positioning strategies among the faculty and administration have begun to take on a new perspective as the mission of each polytechnic is redefined through a formal strategic planning process that includes all of the academic community's constituencies. The concept of enrollment management, once viewed as only an administrative function to admit the best candidates who had applied, is now utilized by many polytechnics to seek out and give counsel to those candidates who would best be served by the type of education at that school. Retaining students has become as important, if not more important, than the recruitment activity. There is a growing shift in perspective by faculty, students and parents toward the view that there needs to be a good "fit" between the aspirations and skills of the entering students and the learning environment so that students may achieve their educational and career objectives. A polytechnic's reputation at the undergraduate level is now being built on that school's retention and graduation placement statistics rather than with its association with and reputation for research.

An example of this new strategy of collaboration that has been documented among faculty and administrators is at the University of Minnesota-Duluth. In 1984 the University made a decision to develop and offer its first engineering programs. Recruitment and retention goals, established in conjunction with the faculty, were based on a common understanding of the program's objectives, the credentials of the students whom they would seek, academic services that would be available to support these students, and the positions these students would seek after graduation. Two years later, the University began to offer its three new engineering programs and had its first graduates four years later. According to the University, they were able to acquire program accreditation and meet their retention and placement objectives. The University attributed much of its success to the working relationships with faculty and staff and their collaborative efforts to outline a process of recruiting students (personal letters from faculty, orientations designed to acquaint the student with the University prior to admittance, making students welcomed after being admitted, and then providing seminars to help students succeed once in the program), a strategy of advising throughout their academic career, and assistance in seeking positions (Luker, 1990). Similar results have been published by Old Dominion, Virginia which also offers engineering programs. While many other polytechnics report similar success at regional and national American Society of Engineering Education conferences, much of this information is anecdotal. However, many other colleges have reported and documented similar success outside the polytechnics (Astin, Korn and Riggs, 1993, Barton and Lapointe, 1995, Brodsky, 1991, and El-Khawas, 1993).

The External Bridges - Prospecting

Creating demand in academe goes back to the Middle Ages when the first entrepreneurial professors traveled from village to village enlisting potential students. This tradition of '"self promotion" has not only continued with today's colleges, but has grown in sophistication as business marketing strategies have been applied to student recruitment. With fewer qualified students, faculty from the academic and professional societies, such as the Professional Engineers in Education of the National Society of Professional Engineers, have also collaborated to promote the disciplines. Unlike previous years when colleges waited for high school seniors and their parents to contact them, many of today's recruitment activities are being directed towards elementary and junior high school students as well as other non-traditional groups such as women and minorities.

Advocates for these new collaborations have also grown as the number of new women and minority faculty have been attracted to the polytechnics (McHenry, 1991). Organizations such as the Society of Women Engineers (SWE), Society of Hispanic Professional Engineers (SHPE), American Indian Society of Engineers and Scientists (AISES), and National Society of Black Engineers (NSBE) have created a number of local and national programs to encourage young children to consider careers in their respective fields. As women and minorities achieve national recognition and status as officers and leaders in the traditional white male dominated professional societies such as the National Society of Professional Engineers (NSPE) and the American

Institute of Architects (AIA), society sponsored recruitment programs have been developed and supported to increase interest in their professions. One early attempt by the engineers was the national program titled MATH COUNTS. This program encourages elementary school students to think about a career in engineering and to continue with their mathematics and sciences once they enter junior and senior high school. [2]

Several other high school programs have been developed and replicated to encourage young and non-traditional students to enroll in the polytechnics. Nationally known programs include the Philadelphia Regional Introduction for Minorities in Engineering (PRIME) that is aimed at upper grade elementary students, Mathematics, Engineering, Science Achievement (MESA) that focuses on the development of a high school student's mathematics, sciences, and engineering skills and knowledge, and Minority Engineering Programs (MEP) that is sponsored by the engineering deans to inform minority students of careers in engineering (McHenry, 1991). Locally, MassPEP is a non-profit organization that works with Boston and suburban high school minorities to encourage them to consider careers in engineering by providing a variety of after-school programs. Many of these programs take the students on field trips to industry and have practitioners make visits to the schools.

The following is an example of collaboration between a polytechnic and a professional society. The Massachusetts Academy of Mathematics and Sciences has joined Worcester Polytechnic Institute (WPI) in developing and offering a pilot magnet school on the WPI campus in the Fall of 1993. It is a state-supported program that allows local school districts to enroll their most gifted students in the program. The educational opportunity is to challenge these students with courses in mathematics and sciences as they prepare themselves for a career in engineering or sciences. In addition to working with the students, high school teachers are also invited to the academy as visiting scholars to work with WPI's faculty. This part of the program is designed to reeducate these high school teachers so they will be better prepared to work with the students in their high schools. A major objective is to begin to remove some of the barriers that have existed between college faculty and junior high school teachers (Samanas, 1993). Similar programs have also been developed with several other local colleges in Massachusetts (MIT, Boston Architectural Center, Boston University and Tufts) to provide summer inquiry programs for students thinking of a career associated with one of the polytechnics. Since many of these programs are relatively new, we do not know what their impact will be on the number of new non-traditional students in the polytechnics.

Another form of collaboration among the polytechnics and high schools is the federally-funded program called Tech-Prep. This program funds specific collaborations among the vocational high schools and the colleges to upgrade the academic curriculum at these schools and to help prepare future graduates obtain a degree in a technical field. The program also provides support for college faculty to work with the vocational teachers to upgrade curriculum and to provide teacher development.

There are a number of workshops and seminars that are also provided throughout the country with support from the polytechnics, professional societies, and industry to encourage young women to obtain an education in science, engineering, and technology. Many of these programs encourage junior and high school women to continue with their mathematics and provide women role models from a variety of technical and professional areas. The Society of Women Engineers is a key sponsoring organization in recruitment programs at the colleges and in the high schools.

The Foundation for Independent Higher Education and the National Institute of Independent Colleges and Universities reported that in 1991, 52% of its 946 member schools had established their own special recruitment programs with local high schools and the professional societies (Vetter, 1991). Common among this prospecting strategy were tactics that included developing educational programs that were directed at instructional preparation and skill enhancement, supporting at-risk students, and preparing motivational programs to encourage non-traditional students to attend college and the polytechnics in particular (Association of Independent Colleges and Universities in Massachusetts [AICUM], 1991).

Bridge One - Recruitment is concerned with the internal and external strategies to increase the pool of candidates and to increase the number of entering students at the polytechnics. The next academic bridge used by the polytechnics to close the learning gap involves curricular modifications and the process of placing students into appropriate courses.

Bridge Two - Curricular Modifications

Once a student has been admitted to the polytechnic, there are a number of strategies practiced to retain students. The approaches generally have one or more of the following objectives: provide a transition for students from high school into the academic program, adapt courses to entering student learning skills, and provide additional motivation and encouragement to improve the persistence rate of students to complete a program. Specific tactics are now described.

An Assessment Strategy - Beyond the GPA

Although high school grade point averages and SAT scores are helpful in determining if a student is academically prepared to start a degree program, they are still not the best indicators in determining if a student will be a drop-out or will complete his program once enrolled (Schreiner, 1988).

For many years it has been acknowledged at regional and national meetings of deans of engineering and engineering technology that the students who would benefit the most from the additional learning resources provided at the polytechnics are those students most “at academic risk”. However, the more motivated student who is looking to better his grade point average is generally the one to take advantage of these additional learning services. In response to this problem, a number of polytechnics have implemented various programs like “early alert” in which faculty have been able to identify those most “at academic risk” based on attendance, completing homework assignments and mid-semester grades (Fidler and Fidler, 1991).

Another approach to modify the curriculum has been the use of nationally developed college student survey which have been used by the polytechnics at summer orientations to determine those risk factors that would prevent students from succeeding in their courses or from staying in the program. These surveys look at a number of risk factors such as study habits, intellectual interests, academic confidence, desire to finish college, attitude towards educators, self-reliance, ease of transition, openness, sense of financial security, receptivity to academic assistance, receptivity to personal counseling and receptivity to career counseling. The results are then shared with the student’s faculty advisor and others such as staff mentors who have been identified to work with the student throughout his college career and to suggest other course work to strengthen the student’s potential for academic success.

In some instances, the polytechnics may refer students for special one year programs that have been designed to build personal confidence and academic preparation. Local Massachusetts colleges offering engineering programs that use this strategy include University of Massachusetts at Lowell, Boston University and WPI. The American Society of Engineering Educators (1994) has reported that 30% of the polytechnics have developed and implemented one year pre-engineering or pre-technology programs to assist their students. Wayne State University in Detroit has a required seven-week program for all its entering freshmen based on assessment tests. These programs are focused on a variety of learning and social skills considered important to complete a program. These assessment bridges are also being used as a base for creating course modifications by the faculty.

An example of attempting to improve the retention rates of students in an introductory course was reported by the faculty at North Carolina State University (Fedler, Forrest, Baker-Ward, Dietz & Mohar, 1993). For many years the University's College of Engineering had reported that they were experiencing a 50% attrition rate (46% being the national average) for all students, and a 70% rate for minorities (p. 15). Various instructional approaches to improve retention had been attempted by a number of faculty including collaborative (team and group) learning techniques (to be discussed later in this chapter), writing across the curriculum (a technique used by a number of polytechnics that involves faculty from the humanities, social sciences and technical areas), and special problem-solving exercises (or critical thinking courses). However, since these attempts were generally isolated and not reinforced by all faculty throughout the student's academic career, student retention in the programs did not improve significantly. The faculty then decided to implement a specialized assessment program to determine what risk factors could be isolated and addressed to improve student retention in the introductory courses, such as chemistry, that were required of all engineering students. In this particular case, risk factors included class attendance, completion of homework assignments on a regular basis, participating in after class tutoring programs, the timely completion and writ-ups of laboratory experiments, high school mathematics achievement and scores and the taking of prerequisite and corequisite mathematics in the curriculum. From the data that has been collected, intervention tactics by faculty advisors have been created to provide additional assistance to the students and alternative learning strategies have been employed such as requiring students to participate in group study sessions. It has also been reported by these schools that student retention has modestly improved overall.

Courses as Bridges -Try Something

There have been a number of attempts by the polytechnics and their faculty to adapt their courses to the realities of incoming students skills and preparation. It has been reported by ACE that over 80% of colleges today offer some remedial courses in mathematics and English. Polytechnics offering remedial courses are not allowed by program accreditors like the Accreditation Board for Engineering and Technology (ABET) to count these courses toward graduation requirements.

In an attempt not to dilute existing courses, a number of polytechnics have also joined the many colleges throughout this country by offering a freshman seminar course(s) (Fidler and Fidler, 1991, Henderson, Desrochers, McDonald and Blard, 1994, and Schriener, 1988). These first-year or first-semester seminar courses are being designed to improve academic performance and student persistence in college. In the National Survey on

Freshmen Seminar Programs (Fidler and Fidler, 1991), it has been reported that all participating schools indicated a 76% retention rate for those students going into the sophomore year with a higher rate of 86% for private schools. Of the topics included in these special seminars the most recurring topics reported were: academic planning (75%), library skills (70%), value of college (69%), study skills (68%), managing text anxiety (68%), reading (68%), career planning (63%), general orientation to the campus (57%), general orientation to health education (57%), and stress management (51%). In all reports, group building and writing skills were also considered important. Also reported in this national survey of freshman seminar courses was that less than 10% of those schools surveyed reported any planned assessment of their programs and that only 30% of those assessing the results of their courses actually included retention statistics. This lack of information appears to be a common problem since many polytechnics, out of frustration with their high student attrition, are quick to just try something to "fix" the attrition problem.

While these freshmen seminar courses are designed to address the larger number of entering students, faculty and departments have also designed strategies to address retention in individual courses.

One technique that is growing in popularity at many of the polytechnics is called Continuous Quality Improvement (CQI). This approach has grown from a number of academic assessment models and from the business precepts supporting Total Quality Management to exceed customer expectations for service or goods. At Penn State's Engineering College, it has been reported (Wolgemuth, 1993, p. 15) that a CQI team of faculty, administrators, and students was formed to improve the University's introductory course in physics offered to its engineering students. As a result of their data collection process and analysis (classroom observations and student surveys), a number of new initiatives have been implemented. These have included the publication of a study strategy guide for all students, improved training of teaching assistants, increased contact time for each student after class with the faculty members, directing “at risk” students to a one-credit concepts course before they enroll for the introductory physics course, and improved "policing efforts" to be sure that students are doing their homework assignments. This approach was declared successful at Penn State but has yet to be duplicated within the same institution or at another college.

Other approaches to improve student motivation and retention have included the use of cooperative work experiences (Meade, 1992) and the use of laboratories to augment lectures in the disciplines. Still other approaches at the polytechnics include a reexamination of the curricular structure in which the present system of taking courses sequentially until one or two skills are learned are being replaced by a system called concurrent engineering that utilizes cross-disciplinary team approaches in the classroom.

> A new construct for systemic change in baccalaureate engineering education is suggested in terms of a taxonomy of intellectual components connected holistically with a core focus on developing human potential, as opposed to the present system in which students are passed serially through course filters (Bardogna, Fromm and Ernst, 1993).

The thrust of the cross-disciplinary team approach is to counteract the concern that entering students are leaving the discipline because they are only exposed in the first two years of study to theoretical courses such as mathematics, sciences, and computer science, and not to their discipline and application courses like electronics, statics, fluids and other similar courses. Because students are not exposed early in the curriculum to their major and appropriate design courses-the real courses until their junior year, many students leave the disciplines for a lack of adequate motivation or incentive (Bardogna, Fromm and Ernst, 1993). The other significant benefits to this approach on the learning experience will be discussed in the next section.

In an attempt to attract and retain women, minorities, and other non-traditional students, at the polytechnics, a number of schools have developed joint programs and multiple degree options. The University of Rochester offers its engineering students a fifth-year of undergraduate work in the liberal arts - free of charge. Columbia University and The Colorado School of Mines offer their engineering and technology students a number of not-for-credit seminars and elective courses in topics designed to attract and retain the engineering undergraduates. Some of these topics include Engineering and the Quality of Life, Leadership, Public Policy and Engineering Ethics (Florman, 1993). Other schools like MIT and Rochester Polytechnic Institute (RPI) have developed a number of interdisciplinary courses and programs under the general heading of Science, Technology, and Society (STS) in which social science and engineering faculty collaborate in their teaching programs. Worcester Polytechnic Institute has developed a nationally recognized program called the Interactive Qualifying Project.

> All WPI students are required to carry out a project (sometimes teamed with fellow students from different fields, but always under the guidance of professors from different disciplines) on interdisciplinary themes, such as “Energy and

> Resources," "Environment and Technology," and "Science and Technology/Policy and Management" (Kranzberg, 1993, p.29).

The Engineering Workforce Commission (1993) had determined that about 60% of all graduates of engineering programs eventually enter positions in management. To attract and retain students a number of polytechnics have developed internal program articulations with their own business departments to offer students a second degree in five years at the graduate management level. Again, it is difficult to assess if any of these approaches have really made a difference in attracting new and non-traditional students or have helped to retain students once in the program. Many of the solutions appear to be based on local conditions and are not easily transferred to other locales. Despite this, other educators are asking some basic questions regarding the curricular structure of the polytechnic programs and the pedagogy. The following is a discussion of these curricular structural changes now under consideration which could, in the long-term, be approaches that could attract new students and retain them.

Curricular Strategy- Challenge the Status Quo

Sheila Tobias writes in her book, They're Not Dumb, They're Different: Stalking the Second Tier (1990), that "we have to identify the able students who are choosing not to pursue science; find out why they are put off by science and attracted to other occupations; and, if necessary, change the recruitment, reward, and opportunity structures to match their temperaments and needs (p.7)." In studying those students who appeared to be bright enough but were just not interested in science and technical careers, Tobias concluded that both the pedagogy and structure of courses and their content needed to be redesigned to give future students an opportunity to holistically view engineering design and problem-solving. The students will need to understand that these processes are complex issues requiring an understanding of the contexts in which these solutions will be implemented. Tobias' book has had a major impact on educators and professionals alike. In describing their new engineering education model that has a focus on developing human potential, Bardogna, Fromm and Ernst (1993) stress that

> (1) the four-year undergraduate engineering program should be designed to provide the knowledge base and the intellectual capability for "career long" learning, (2) the focus for undergraduate engineering education should be the development of students as emerging professionals rather than completely trained engineers, (3) the student should be a willing - preferably an eager - participant in the process of learning and should be a satisfied customer of the process, and (4) evaluation should move from a focus on end-item-inspection to forms compatible with a goal for continuous improvement of both students and capability and of the engineering education process itself (p.7).

Major features of this approach that differ from traditional engineering education models today include an expanded use of hands-on labs, design, and systems methodologies in the first two years of study; integrated, unified science and math courses in the first two years; and in-depth interdisciplinary problem-solving in the last two years. A bridge that these and other writers on the education of polytechnic professionals, such as Lynton (UMass-Boston) and Schon (MIT), are trying to create is one in which

> the content of the career-oriented major itself will be expanded to allow students to acquire the necessary understanding of the context in which they will function as practitioners, and of the ethical and legal issues which they will confront. The approach should be one of assessing technology, focusing on the societal and organizational impact of new technologies, on their positive potential and their downside risks, and on various ways in which they can be used (Lyton,1990, p10).

Curricular modifications used as bridges to close the learning gap have consisted of three major approaches. The first was the development and introduction of general seminar courses to reach students in the first year. The second approach was to modify existing courses in the curriculum by including more remedial information and to rely on cross departmental teaching. The third approach was to re-examine the purposes of the educational process and to change existing instructional paradigms. Success to date has been subject to a schools own inclination towards reform and the need to retain more students. Because of a lack of data and continuous assessment there is not sufficient evidence that the results of these programs can be replicated and successfully duplicated at another school. We will return to the topic of curricular structure in the discussion of Academic Bridge Four - Pedagogy. The following section, Academic Services, examines the bridges that have been developed by using academic and administrative student support services.

Bridge Three - Academic Services

" A vital part of any retrenchment strategy is the improvement of productivity (Coate, 1992. P.1)." During the mid-1980s several tactics were developed to increase student retention by improving the quality of the polytechnic's student services. Several themes evolved as specific tactics and programs were developed and implemented. The most common approach was that of encouraging all members of the polytechnic to shift the emphasis on developing and delivering the academic and student services from a passive to a proactive approach (Frost,1991). Other approaches included challenging the collective "mentality" of the polytechnics from thinking that "we know" what the students want and need to one that emphasized "asking" the students what they needed and wanted to succeed academically once on campus, (Higgins, Jenkins & Lewis, 1991). Focusing on incremental improvements, additional techniques included creating a new perspective that went beyond the initial developing and offering of services to looking for ways to continuously improve those services once offered (White, 1993 Chaffee and Sherr, 1992), and involving the student (client or customer) in the development, implementation and assessment of all student-directed services (Engelkemeyer, 1993).

The first attempts to improve student academic and administrative services were based on the simple premise of enabling students to focus on their academic studies. By offering timely services to resolve as many of the non-academic problems as a student encounters there was a better chance that the student would succeed in the classroom. Initially, this theme was adopted by the non-academic areas such as housing, food services, the bookstore, student financial services and financial aid and student parking. As students reported satisfaction with the assistance they were receiving at the campuses, the traditional academic support services such as the registrar's office, library, continuing education, learning and other academic resource services adopted similar approaches to help in the overall retention efforts on the campuses (Coate, 1992, Luker, 1990, Clough, 1993, Engelkemeyer, 1993 and Seymour, 1993). Most of these programs emulated the business applications of Total Quality Management (TQM) previously discussed in Chapter Two and from the writings of TQM gurus such as Shewhart, Deming, Juran and Crosby (Coate, 1992 and Fisher, 1993). These business approaches were intended to make continuous improvements in the product or services of the organization and to help employees focus on exceeding customer needs and wants for these products and services. By the 1990s a number of these approaches began to influence the delivery of the academic programs at polytechnics such as Penn State Engineering College's efforts to implement Continuous Quality Improvement (CQI) techniques in the classroom that we saw earlier. The following are additional examples of strategies to build academic bridges to retain students by improving the quality of the academic services.

Intrusive Advising

In the report titled Retention Success in Engineering Programs (Luker, 1990), the author stresses the importance of developing processes that are proactive in order to retain students. In this report, she cited a number of examples that were successfully being implemented at the University of Minnesota-Duluth. A number of proactive approaches used included *training faculty* as advisors and mentors, developing student *handbooks that anticipated* student questions, *training students* to work with incoming students, mid-quarter *intervention projects* jointly developed between those in academics and student affairs to target students at risk, and several other ways to *"minimize frustrating* *bureaucratic runabouts.* (p.5)." These proactive approaches also led to the development of what is now typically called "intrusive advising" by a number of the polytechnics.

In her book Academic Advising for Student Success (1991), Susan Frost outlines several recommendations to improve student retention that were based on extensive research of existing advising systems throughout the United States. Chief among these recommendations related to intrusive advising techniques included: (a) designing an advising system centered around getting students involved in their learning outside the classroom and creating positive academic outcomes, (b) promoting concepts of shared responsibility for academic success by the students and institution, (c) beginning the advising relationship with an awareness of a larger educational purpose, (d) planning the advising system for success, (e) evaluating the advisory system and making changes as needed, and (f) building into the advising system a real collaboration with others outside the academic departments.

Unfortunately, most faculty advising systems today are not much different than those developed in the early nineteenth century. These antiquated systems were originally created to assist students in selecting elective courses that had just been introduced into the curriculum (Frost, 1991). Frost concluded that student learning was directly proportional to the quantity and quality of a student's own involvement and by those responsible for delivering the academic programs. In turn, educational effectiveness was directly related to the capacity of a policy or practice to increase student involvement. She argues that "various types of contacts on campus are important in causing students to persist and that integrating with faculty outside the formal boundaries of the classroom seemed to be particularly significant in retaining students (p.9)."

Further, “those students with meaningful faculty advising and peer relationships were also less likely to become dropouts (P.11).”

Frost developed a series of student characteristics to assist in the development of advising programs for academically under-prepared students.

> Many under prepared students seem to lack basic skills in language, writing, and computation and study habits. Some have unfocused career objectives, are unmotivated, expect to fail, and do not graduate. Under prepared students need skills that allow them to achieve on the same levels as students who are adequately prepared. They also need to expect and experience success. They lack confidence and hesitate to seek available support (p.29).

Frost also proposed a series of techniques that would form the basis for intrusive advising. Chief among them were establishing a trusting advising relationship early in the advising process and beginning with intrusive advising tactics. Some of these tactics included required meetings with the advisor, freshmen seminars, orientation workshops, discussing the purpose of a college education early in the advisor-student relationship, and encouraging the development of basic academic survival skills. These tactics were then followed up with recommending other intervention programs and campus resources when needed. These approaches are likened to some of the health care reform recommendations in which a primary care specialist (the faculty advisor) directs the client (student) to specialists when needed (counseling, learning centers, mentor programs, etc.).

Intrusive or intervention advising models are found to be most effective when there is concern for students as individuals, a close interaction between faculty and new students can be established early, there is an emphasis on academics in the advising system, advising is conducted in small groups, attractive program material can be developed and provided, and there is an awareness of institutional resources by the student and advisor (Frost, 1991, Luker, 1990).

Learning From the Student

After years of implementing student course evaluations and surveys, faculty and administrators have begun to listen to what the students are actually saying about the educational programs and services. "As educators we all listen to our students, right? Do we always hear what is really said? (Higgins, Jenkins and Lewis, 1991, p. 12)" Thus begins the report of three faculty members from the U.S. Army School of Engineering and Logistics and a process that was begun by President Derik Bok at Harvard University in the 1980's. To answer this question, these faculty sought out to establish an ongoing dialogue with the students and other faculty from within their programs to compare what each considered good teaching. In the process, they found that the listing of specific items were less important (although only half of the top ten items on each other's list were similar) when compared to the openness and attempts to improve the quality of teaching by listening to the students. Another example of listening to students is what has been now called the Herschback Approach (Tobias, 1990). Professor Herschback, a chemistry teacher at Harvard, would ask his students at the midterm how they were doing in learning about the subject material in the course and also ask for suggestions so that he could make appropriate adjustments to improve his teaching effectiveness. His approach became a model for a number of faculty at Harvard.

With the introduction of Total Quality Management (TQM) techniques has come a rush of questions directed at the central purposes of the academic enterprise. One such question has been how is the student a beneficiary of the educational process (Chaffee & Sherr, 1992, Clough, 1993, Engelkemeyer, 1993, Coate, 1992).

> A faculty member at the University of Wisconsin resolved the dilemma by defining students as beneficiaries of the teaching process, but not its content. The instructor created a small team in each of his classes, working with students to define needed improvements in such areas as the clarity of the transparencies and the utility of the computing manual. He retained the authority to make decisions about what to teach and what teaching methods to use (Chaffee and Sherr, 1992, p. 80).

As a result, students have taken on a more active role for their own learning and were better prepared for class discussions.

A coalition of nine universities, called the Southern University and College Coalition for Engineering Education (SUCEED), set out to determine and “use new methods of delivery technology to enhance the learning process (Clough, 1993, p.9)” and retain students by using TQM techniques. This particular effort was supported by a grant from the National Science Foundation to improve the quality of the engineering curriculum. One result of this collaboration was a shared use of computer technology developed by faculty for the classroom among their coalition members which in turn stimulated student involvement in the subject material.

Although there are numerous other examples of utilizing TQM or other fashionable techniques to assist the less-than-prepared students such as at Georgia Tech (White, 1993), Virginia Tech (Clough,1993), Syracuse University (Shaw, 1993), University of Wisconsin (Role of Academia in National Competitiveness and Total Quality Management, 1991) and Oregon State University (Coate, 1992), most have not been in place long enough to assess their success and value against their stated objectives. Preliminary reports by these institutions, however, do indicate some positive qualitative gains towards meeting their objectives. In addition, attitudinal changes by the faculty towards student retention on their campuses have also been reported by these same groups.

The introduction of Total Quality Management techniques were initially designed to improve the effectiveness of support services to students with the objective of improving overall student retention. The concepts taught at the business schools were then applied to the University's academic units. Although acceptance has been slow by the academic units and their faculty, many of the polytechnics and other colleges have begun to notice an attitudinal change to creatively work with the students to improve retention. Now at the polytechnics, advising is seen as a tool to improve student retention as well as assisting the university in achieving its educational objectives. Advising is no longer viewed as merely the way to register for courses or give career counseling to students. This process of directing one's attention to improving the quality of services to the students has also led to more faculty opening up to each other at the polytechnics and the sharing of instructional techniques with their colleagues. This now leads into the last academic bridge to be discussed- the polytechnics' pedagogical paradigm.

Bridge Four - Pedagogy

The pedagogical paradigm at the polytechnics is steeped in the traditions of lecture, topic specialization, sequential learning (numerous prerequisite courses), familiarity and use of repetitive problem-solving techniques, and evaluation systems and teaching strategies that perpetuate the concept of winners and losers. Traditionally, the faculty at the polytechnics graded students in their classes based on a statistical curve - usually a “bell shaped curve.” As a result, there was always a percentage of students in the class who would receive “A” grades even if the performance of all students exceeded the quality of “A” work of students in the past. Generally, high achievement was also a factor as to who would receive scholarships or go on to graduate school, thus causing a sense of winners and losers. This approach to performance evaluation had greatly influenced the teaching styles and attitudes of many faculty and graduates who have gone into industry and then returned as faculty themselves. Faced with not being able to attract sufficient numbers of academically prepared students and increasing student attrition rates, the polytechnics are now seriously asking questions related to what they teach and how they teach.

There is a strong belief in the American culture that you are born with the learning skills and other abilities to succeed in life (Magaziner, 1992). Therefore, the purpose of "school" is to bring focus to these innate skills and abilities to help the individual succeed in the future. By only accepting the top 5 to 10 percent of the graduating high school class in the past, the polytechnics have perpetuated this belief and another belief that bright students will learn despite the faculty.

Felder and Silverman, faculty from North Carolina State University, reported in a study titled Learning and Teaching Styles in Engineering Education (1988), that there was a mismatch between the learning styles of the engineering students and the teaching styles of the engineering faculty. They concluded that most of the engineering students' learning styles were visual, sensory, inductive, active and for some of the most creative students, holistic thinkers. In contrast, the teaching styles of the engineering faculty emphasized the use of auditory, abstract (intuitive), deductive, passive and sequential learning. "These mismatches lead to poor student performance, professorial frustration, and a loss to society of many potentially excellent engineers (Felder & Silverman, 1988, p.680)." Although problems of student retention relating to discontinuities between teaching and learning styles had already been identified in the literature (Kolb, 1984, p. 163) and coupled with the fact that fewer students apply to the technical disciplines, it was not until the number of less-than-prepared students reached a significant proportion of the entire class (25 to 50 percent of those entering first year students), that this issue became a major concern at the polytechnics.

The discontinuity between learning and teaching styles became more evident to educators at the polytechnics when the book by Shelia Tobia, They're Not Dumb, They're Different (1990), was published. Her study focused on the question why capable students in mathematics and sciences stayed away from the science, engineering or technology disciplines. She concluded that a change in the classroom culture was essential if academically prepared and non-traditional students were to be attracted into these programs. Students identified several reasons for not considering or applying to these disciplines. Chief among these reasons were the emphasis on competition at the exclusion of collaborative team work in the classroom, an excessive pace of the discipline courses to cover material, the lack of in-depth discussions of subject material and its context by faculty, teaching methods that focused on the tools and the proficiency in using these tools versus developing an understanding for the whole design process, the lack of examples, and the amount of classroom lecture.

Evolving from the previous apprenticeship programs and early teachings utilizing the scientific method at the polytechnics and the writings of researchers studying learning behaviors, two pedagogical strategies have begun to emerge. These strategies, experiential learning and collaborative learning will now be discussed.

The Experiential Learning Strategy

David Kolb (1984), a faculty member at Case-Western University (a polytechnic) studied and expanded the previous research of Dewey, Lewin, and Piaget on experiential learning. He developed a learning model that has since been applied by faculty from other polytechnics such as at the University of Texas (Svinicki and Dixon,1987), University of Pennsylvania, Drexel University and University of South Carolina (Bardogna, Fromm, Ernst, 1993). A foundation to the work reported at these institutions and on Kolb's earlier studies in experiential learning (1984), has been that learning is a holistic process involving numerous transactions between the person and the environment. As individuals become engaged in this process, the potential for creating new knowledge and the re-thinking of previous solutions to new circumstances exists. From a pedagogical perspective, learning is best conceived not as a sequential teaching of courses or topics, but as a process that is continuous, grounded in experience, and "requires the resolution of conflicts between dialectically opposed points of view (Kolb, 1984, p.30)." The four cycles to the experiential learning process are concrete experience, reflective observation, abstract conceptualization and active experimentation.

> The cycle begins with the learner's personal involvement in a specific experience. The learner reflects on this experience from many viewpoints, seeking to find its meaning. Out of this reflection the learner draws logical conclusions (abstract conceptualization) and may add to his or her own conclusions the theoretical construct of others. These conclusions and constructs guide decisions and actions (active experimentation) that lead to no concrete experiences (Svinicki and Dixon, p.146).

Good teaching is not only being enthusiastic and knowledgeable but also requires an understanding of the learning process. Too frequently, administrative programs designed to address retention issues, like orientation and counseling, are substituted for quality instruction (Cross, 1993, p.7). For the polytechnic students who are primarily visual and auditory learners, this means that presentations and assignments must be modified to address their learning styles.

> The point is made by a study carried out by the Socony-Vacuum Oil Company that concludes that students retain 10 percent of what they read, 26 percent of what they hear, 30 percent of what they see, 50 percent of what they see and hear, 70 percent of what they say, and 90 percent of what they say as they do something (Stice, 1987, p 291).

Several suggestions have been made by these researchers to enhance a faculty member's teaching style and to take full advantage of the four types of experiences embodied by the experiential learning model. These types of experiences are now discussed.

To foster the initial concrete experiences of students the use of activities such as laboratories, observations, simulations/games, field work, problem sets and examples are recommended. To stimulate the activity of reflective observation the use of student logs, journals, extended discussions, brainstorming activities, thought questions and rhetorical questions are encouraged. To enhance the cycle of abstract conceptualization, the use of the lecture, student papers, model building activities, and term projects has been recommended. Active experimentation is a cycle of learning that is best adapted to activities such as simulations, case study, laboratory, field work, projects and homework (Svinicki and Dixon, 1987).

Other recommendations have been developed to enhance teaching effectiveness using the experiential learning model. Suggestions to faculty have included making attempts to relate the course material to the student's own personal experiences and thus making it easier to understand the material in context. Other suggestions have been to provide a balance of concrete information and abstract concepts during lectures so as to help the student better understand sophisticated approaches. Also, a balance in classroom material with practical problem-solving techniques that emphasizes fundamental understanding through application has been recommended. This can be accomplished in a number of ways such as the use of laboratories or assigned homework or projects, providing visual materials that support the concepts being discussed, not filling every minute of class time with lecturing or writing on the board but allow students to think about what they have been told, assigning some drill exercises to better understand theory discussed in class, applauding creative solutions, and talking to students about learning styles as advisors (Felder and Silverman, 1988, p.680).

In 1992, a pilot program at the Beaver Campus of Penn State was implemented using the Kolb Experiential Learning Model and its four cycles of learning. The University reported a 30% increase in retention into the second year when compared to the previous year's entering engineering cohorts (Wolgemuth, 1993). Similar results have also been reported. At Harvard, the Herschback Approach previously discussed in this chapter, emphasizes a “cover less and uncover more” approach that has led to "substantial increases" in student retention in their basic chemistry and other science courses (Tobias, 1990, p.60).

In addition to improving student retention by better matching teaching styles to the student’s learning styles, experiential learning is also an approach that can build academic bridges with those students who are initially academically under-prepared.

Studies conducted on the "at-risk" college student suggest that it is important that these students be first motivated to take on responsibility for their own learning. For the less-than-prepared student, experiential learning models are well adapted to assisting metacognitive strategies for teaching self-control through activities designed to improve personal performance. Several suggestions for developing this responsibility parallel learning experiences described by Kolb and others. They do this by requiring students to reflect and act on their own experiences in order to develop the necessary self-confidences to learn about other new experiences. However, the biggest obstacle to using an experiential learning model is the faculty’s own comfort level with lecturing based on their own past experiences (Mealey, 1990, Oreovcs, 1994, and Synder and Edwards, 1993).

The next strategy also challenges the faculty's reliance on lecturing and its value in the learning process.

<u>The Cooperative Learning Strategy</u>

Whereas the experiential learning model focused on the individual learning style of students at the polytechnic, cooperative learning examines the role of developing group skills to advance the learning techniques of individual students. Cooperative learning strategies attempt to increase a student's involvement in his/her own college learning experience - a factor that has been determined to significantly improve student retention (Cross, 1993 and Johnson, Johnson and Smith, 1991).

> The lecture came into prominence when it was assumed that John Locke was correct and that the untrained mind is like a blank sheet of paper waiting for the instructor to write on it, and that students' minds are empty vessels into which instructors pour wisdom. Because of these and other assumptions, faculty lecture. Moreover, faculty often think of their job in terms of three main activities:
>
> 1. To impart knowledge, that is, the faculty's job is to give and the student's job is to receive;
>
> 2. To classify students, that is, decide who gets which grade;
>
> 3. To sort students into categories, that is, to decide who does and who does not meet the requirements to be graduated, go on to graduate school, and to get a good job.

> Faculty must "add value" by developing students' potential and transforming them into more knowledgeable and committed individuals. A cultivating philosophy must replace a weeding out philosophy (Johnson, Johnson and Smith, 1991. pp. 82-83).

Proponents of the cooperative learning experience have referenced over "90 years of research that have produced over 600 studies demonstrating that cooperative learning results in higher achievement, more positive relationships among students, and a healthier psychological adjustment than does competitive or individualistic learning (Johnson, Johnson and Smith, 1991, p.1)."

To create a cooperative learning experience, a student group must have a clear positive interdependence, must promote each other's learning and success face-to-face, and hold each other individually accountable to do his or her fair share of the work. For this strategy to succeed at the polytechnics they must "change from a competitive/ individualistic mass-manufacturing structure within which the faculty work alone to a high-performance, team-based organizational structure in which faculty work as teams (Johnson, Johnson, & Smith, 1991, p.115)." This can occur through the development and encouragement of frequent discussions among the faculty of different disciplines. In time this can lead to co-planning, co-designing, co-evaluating, co-teaching and reciprocal observations of each other's teaching lessons. Previous research has also indicated a significant and positive impact on retaining students (Johnson, Johnson & Smith, 1991).

A major reason for students dropping out of their polytechnic program has been attributed to their failure to develop a network of friends and classmates to become academically involved in classes (Astin, 1993, Johnson,

Johnson & Smith, 1991, Cross, 1993, Tobias, 1990, and Oreovcz, 1994). The five-year retention rate for African-American students majoring in mathematics or science at Berkeley who were involved in cooperative learning, for example, was 65 percent, compared to 41 percent for African-American students not involved (Brodsky, 1991 and McHenery, 1991).

Calls for the use of cooperative learning strategies at the polytechnics is a recent development at the polytechnics, although components have been used in the project and design courses for years. Two faculty members at Purdue University's College of Engineering, have begun to apply this approach to their freshmen courses and have noted an increase in their own students' active involvement for their education (Oreovcz, 1994, pp. 15-19). One result of their research has been the development of workshops for the American Society for Engineering Education's Fourth Annual National Effective Teaching Institute this past June, 1994.

In the past, the pedagogy used at the polytechnics was simply the result of new faculty repeating that which they experienced as undergraduates themselves. It was assumed that their own success was the result of the teaching techniques learned years ago. It was not until the academic preparation of students began to change that faculty also began to question the relationship between learning and teaching styles. Fortuitously, this coincided with research then being conducted at the universities on teaching styles and pedagogy to improve student retention. As a result, faculty at the polytechnics have become more open to new ideas regarding teaching methods from those outside their own disciplines. Results outside of the polytechnics indicate that student retention can improve when there is a better match between student learning styles and the teaching styles of the faculty.

We can see things more clearly by reviewing the results of one polytechnic's efforts to incorporate a number of these strategies previously discussed to retain and bridge the less-than-prepared student's learning skills and abilities to the needs of the curriculum.

A Case Study

Wentworth Institute of Technology is a nationally recognized polytechnic institution offering undergraduate programs in technology, management, and professional degree programs (leading to professional registration) in architecture, engineering and interior design. Wentworth has experienced the same problems of recruiting and retaining students as their colleagues at other polytechnics. During the late 1980's Wentworth's overall student population declined from a high of 4,020 students in 1986 to 2,960 students in 1993. New students had decreased by about 30% over 6 years. Until 1993, first year fall semester students matriculating into the second semester was 72%. Based on a number of strategies employed, this statistic is now 88% after three years of program implementation. In this section we will review a number of academic strategies that have been used to assist the less-than-prepared students entering Wentworth and that have led to these higher retention rates.

Presently, the median combined SAT scores of students entering Wentworth's degree programs ranged from 850 to 1000 depending upon the program in which they were enrolled. Those students with the higher high school grades and SAT scores generally were recruited into the professional degree programs and those technology programs requiring stronger skills in mathematics. Typically, students displayed the same academic profile as at other polytechnics in that their mathematics preparation was generally stronger than their verbal, reading comprehension and writing skills. Founded 90 years ago, Wentworth has maintained an "open enrollment" admission's policy by providing a number of educational tracks for students to enter and develop their learning and technical skills. These tracks have included certificate programs, two-year associate degree programs, and four and five year baccalaureate programs. In many cases, students are encouraged to complete one level of study and then move on to the next after completion or to seek employment. There is a high acceptance rate by industry and business of the Wentworth cooperative work student (a junior and senior year graduation requirement) and its graduates. Placement rates have remained high (97% placement rate for coop students and 95% for those students using Wentworth's placement services) despite the economy.

Wentworth has worked with employers, professional societies, and other educational institutions at the high school, community college and baccalaureate levels to attract non traditional and better academically prepared students to its campus. Some of these strategies have included annual events co-sponsored by business and industry and foundation support. Various populations have been targeted through activities such as Women in Technology for junior high and high school women, Camp Tech Summer programs for third to eighth graders from Boston, special Saturday programs for local high school students to encourage them to take math and science, and Tech-Prep articulation agreements with local vocational high schools. There has also been several community college articulation agreements to attract academically prepared students who have taken at least one year of college preparation. These articulation agreements allow for the faculty of both schools to review course content and to streamline the number of prerequisites into the program of another school once the student graduates. Where administrators were once the only advocates, faculty have now become active advocates because these articulation programs have increased the number and quality of entering students.

As part of the Institute's campus-wide efforts to recruit students, faculty and staff from student affairs and the admissions office have created a number of programs to meet and talk with applicants and their parents prior to the admission process. Their programs have included summer orientations to help students adjust to college life and the rigors of academic work, and special placement examinations to assist students as they register for the appropriate mathematics level or English courses needed in their selected programs. Additional student testing is accomplished prior to the start of classes to determine those who might be at academic risk based on personality traits and family background. This information is now being used to assist faculty advisors and others in determining what additional learning support can be offered to these students discussed below .

A second academic bridge used by Wentworth has been that of offering special one-year academic programs designed to better qualify a student for admission into one of its degree programs. Other programs that have been implemented include an “early alert system” that identifies students who have the greatest difficulty in the first few weeks of classes, mentor programs that have been designed to work with these "at-risk" students by offering individual advising, peer tutoring through a learning resource center open to all students, and a freshmen seminar program. The freshman seminar program assists new students with their study and organizational skills, social skills needed to develop networks with other students and the resources available to them on the campus, and provides additional counseling to help them survive the first semester of college work. As we saw, the cumulative impact of all these programs in the past three years has been an increase of 15 percentage points in the retention rate of first-year students (from 73% in 1989 to 88% in 1993).

Developed after a two-year study by faculty, staff and administrators, a campus-wide retention committee suggested a number of other recommendations to assist the Institute in retaining students and working with the academically less-than prepared student. In addition to developing specific programs, the committee also brought a sense of urgency to the rest of the campus. It should be noted that during these increases of retention the median scores of students entering Wentworth did not change overall.

As part of this polytechnic's retention task force recommendations, Wentworth had also begun its own work to encourage the use of techniques such as TQM within the student service areas. Based on student surveys that asked students for their basic requirements to allow them to concentrate on their studies, a number of improvements were initiated in the academic and student service areas including the library, registrar's office, academic computing center and student financial services. Improved services to students has made it easier for them to focus on their academic work and thus helped retention efforts.

In addition to this activity a more intrusive advising system was developed based on freshmen and sophomore surveys to address the learning needs of those at greatest risk of dropping out. Additional peer tutoring services were added to assist students and a special mentor program utilizing Arts and Science faculty was created to address these "at-risk" students based on College Student Surveys given during summer orientation sessions.

Although it is not possible to attribute a single tactic to the retention of students, it is believed that the cumulative effects of the academic bridges that have been implemented did contribute to improved student retention and learning at Wentworth. With additional assessment, those programs with no or marginal success will be eliminated and new programs developed. It is clear that student success has generated much enthusiasm as well as a sense of urgency to do something by all on the campus.

Conclusion

We have discussed a number of bridges that have already been developed and implemented at the polytechnics to adapt to the growing number of academically under-prepared students being admitted to the polytechnics. Some of the strategies examined have included techniques to recruit better students, programs developed to create a sense of urgency and team effort at each school, and a number of tactics to address long term learning issues related to incoming students. More promising for the future learning needs of its students are changes and modifications related to the pedagogical paradigm that has aggravated a mismatch between the learning and teaching styles of the students being admitted today.

Chapter Five - Future Bridges will examine the value of these bridges presented in Chapter Four on polytechnic education in the future, and their impact to changes in the industry presented in Chapter Two and at the polytechnics as presented in Chapter Three.

Chapter 4 End Notes

1. Despite declining enrollments, there are now more colleges and more technology programs being offered than at any time previously. This is particularly true as the number of non-accredited programs at state schools have been on the rise as part of their marketing strategies to survive in the ‘90s (Reported by the American Society of Engineering Education, 1994).

2. Local schools and over 5000 students have participated in “Math Counts” each year as reported by the National Society of Professional Engineers (NSPE). In addition to giving students a chance to use their mathematics to solve simple design problems, it also provides NSPE with an opportunity to provide role models to the participating schools.

CHAPTER 5

FUTURE BRIDGES

This chapter will review the major findings of this study regarding the factors that continue to shape and influence polytechnic education, the expectations of employers for polytechnic graduates, the expected level of academic preparation for those who will enter the polytechnics, and the bridges now in place to help less-than-prepared students succeed once at the polytechnics. In reviewing these factors, the original dissertation questions in the introduction will be answered. What are the learning skills needed for undergraduate study at the polytechnics? What are the skills that students will most likely have as a result of their secondary educational experience within the next decade? What are the projected educational needs for a quality and flexible technological workforce in America? Why have previous efforts by the polytechnics to accommodate the poorer entry skills of students or to attract better qualified students failed? What is the projected impact that future entering student skills and skills of an educated technical workforce have on the existing pedagogues and curricular structures at the polytechnics?

Finally, to bring closure to this study, additional bridges are recommended to attract and educate qualified students to the polytechnics in the future and suggestions are made for further studies into bridging the learning gap.

For decades, America's polytechnics have enjoyed a symbiotic relationship with industry and the citizenry. A beneficiary of the technological changes in the United States, the polytechnics attracted greater numbers of bright and motivated students than they could educate. However, today there are fewer academically prepared and interested students seeking professional careers in engineering and technology. This chapter will summarize and put into context those factors that have led to a skills gap for learning and applying technological change at the polytechnics and recommend future bridges to span this gap.

Robert Solow, a renowned MIT economist, developed a simple mathematical model to show that the "impetus for economic growth lay not in the land, capital or labor - traditionally considered most important but in a powerful force called technical change whose determinants lay outside the model (Warsh, 1994, p.81)." By focusing much of this country's economic development and research in technological advancements in the aerospace, defense, medical, electronic, and computer industries, the imagination of many high school graduates was captured. This "capture" translated into increased applicants to the polytechnics from the 1960s through the 1980s. However, America's fascination with technological change has also led to an economic decline in the patterns of daily life. With the displacement of low-skilled jobs, fascination has turned into fear and apathy.

> Higher productivity has led to big layoffs at many companies, especially in the telecommunications industry. Elsewhere, meanwhile, advancing technology is favoring skilled workers over unskilled, increasing the inequality in wages (Moody, 1993, p. 23).

As the number of entry and middle level positions disappeared from the technical workforce, educational and career interests in engineering and technology by high school students and their parents have declined. The decrease in manufacturing and business spending for applied research in the

United States has also contributed to a lack of public support for social policy and fiscal assistance associated with educational programs in science, engineering or technology. This in turn has contributed to the decline in support for quality instruction in mathematics and science education in grades K-12 - the foundation blocks to this country's future technological developments.

Although America could generate new and interesting ideas from its research and development efforts, it continues to lag in its ability to bring these innovations to the marketplace and successfully compete with other nations. With much of the world's manufacturing foundation shifting from mass-production to flexible and technically sophisticated and efficient manufacturing systems and to an "information economy", so called American "know-how" is being exported to other countries (Moody, 1993). The impact of this loss of manufacturing skill was disguised somewhat by the parallel development of new wealth in the 1970s and 80s. This new wealth was being created in the United States by the expansion of the service industries (legal, financial and entertainment). The change from the creation of wealth through our technological advancements to the sale of these ideas and resources to others has been a major factor in the decline of the US economy. Out of this shift from production to a service economy has come a decline in the quality of life styles in the US. During this period, "Third World Nations" were implementing economic strategies that first developed the educational levels of their citizens and then "sold" these skills to the industrialized countries like the United States. As a result of this migration of technical "know-how" and experience, there has been a decline in the size and quality of the technical workforce in the United States.

This decline has now begun to directly affect the prestige and growth of the polytechnics as fewer qualified students are being admitted. Once expected to keep pace and parallel America's global reputation for technical creativity, leadership and economic dominance throughout the world, the polytechnics are now paralleling the economic realities and decline of this country's competitiveness.

In the 1950s Robert Solow foresaw the dynamics of technical change as a prominent factor in determining America's future economic growth and direction. However, it is America's competitors who have adopted and used technological innovation to become competitive forces in this global economy. Despite the need and calls to reinvigorate America's technical innovation and entrepreneurship, America finds that its citizens are neither academically qualified nor motivated to address this call to action. As Solow had predicted, technological change has shaped this nation's economy and to a greater extent, the polytechnics' future.

Generated by technological change, several factors are now reshaping the educational environment at the polytechnics. These factors include evolving expectations in industry regarding work design, changing and conflicting business and societal attitudes and values regarding the work ethic, global competition, team collaboration, life-long learning skills, and the level of inertia resisting change in industry, professional societies and at the polytechnics.

A Revolution in Work Design And The Work Place

Expectations of employers of their employees have drastically changed since the mid-1980s. This was brought on by numerous changes including global competition, rapid developments in technology, and attempts to find better and more efficient ways to do the same thing. No longer can firms rely on previous organizational methods and processes in work design that utilized the labor force as expendable components in a series of well-defined processes. Firms can no longer afford to hire and retain individuals who have been educated and trained to be experts in only one or two areas within the firm's business. Today, many organizations need and are seeking individuals who can become initiators, able to act without management direction, develop new math, technical and analytical skills to learn new methods, processes and technologies that are still yet to be invented (Lynton, 1991). Organizations are forced to find ways to reduce their workforce but at the same time increase productivity and competitiveness with innovative processes and technologies. Firms are becoming more effective because they will only hire and promote individuals who are able to utilize technological advancements, contribute to innovative solutions in a collaborative environment and make appropriate local decisions for their areas of responsibility. The successful practitioners must have a developed sense of the marketplace and the needs of their customers, must continuously learn through professional development activities, must articulate their thinking to others inside and outside the firm, and must have acquired the prerequisite learning and technology skills to advance and adapt to changes in the organization.

Although these characteristics are in and of themselves not new, the fact that organizations are now actively and consciously seeking this type of individual is revolutionary. In many ways, these attributes have also been included in standards of accreditation agencies, professional societies and the polytechnics (refer to Chapter One). Many of these problem-solving attributes have been well documented by other studies describing today's revolution in work design (Albrecht and Zenke, 1995, Austin and Gamson, 1983, Galvin, 1994, Kuttner, 1992, Peters,1988, and Reich, 1992). The following example of a medium-sized architectural/engineering firm, Symmes, Maini and McGee Associates in Cambridge, Massachusetts (100 professional architectural, engineering and support technical staff) that has purposely redesigned its work processes to compete in a declining and competitive environment effectively illustrates the change in work design.

In 1986, this firm was twice its present size and offered its professional services primarily in support of other design professionals. A substantial decline in the architectural design and construction environment in New England since the late 1980s had caused numerous firms to fail. Since the majority of this firm's clients were those organizations having financial difficulty, it was clear that not only would new markets have to be developed but the firm would itself have to experience a reduction in staff size to survive. In analyzing their own strengths and weaknesses, it became clear to a number of staff that they had the talent and skills to compete directly with their former clients (the design firms) for architectural and engineering design commissions. But they believed that to do so they had to restructure themselves to be more efficient in providing these services, especially since many of the commissions available at that time were relatively small projects that could not afford much overhead. Whereas other firms sought these smaller commissions to cover their overhead, this firm reorganized to serve a need to provide a quality service and still be profitable.

Typically, architectural and engineering firms have been structured to support a problem-solving process that was technically sequential. The consulting firms brought together specializations or experts to the process as needed, managed in a hierarchical structure including review and decision-making steps and meetings, and utilized technical staff as the support and production tools to implement the design decisions. This process was managed by a few individuals who had achieved a certain level of management authority in the firm based on their technical expertise (Balich, 1976).

In three years, this firm was able to implement a number of strategies that allowed them to halve their staff while increasing productivity and profits by 300%. Several breakthroughs in work design were achieved. By utilizing computer technology (computer-aided-design and drafting) and management information systems (communication networks) they were able to replace laborious drafting techniques and the need for others to convert design sketches into working documents, and to utilize a system that allowed many other specialists to simultaneously work on the problem. Individuals were then assigned to multiple projects, required to take on different roles as team leader or team player simultaneously, work directly with clients to better understand and solve their needs, and were made responsible to the firm for the budgeting of the firm's resources. There were a number of parallel tactics to reward and promote team successes and personal professional development. Permanent titles were all but eliminated (corporate officer titles remained for external and legal reasons) and the organizational structure focused on supporting individuals who were responsible for the firm's clients. Weekly firm review sessions were implemented with the entire staff to improve design quality and overall productivity. Those who stayed with the firm during this period had exhibited the personal characteristics previously described.

There are many other examples of this type of change in work design going on each day and retold through the professional journals and newspapers. In Massachusetts, despite many years of losing manufacturing jobs to other regions of this country and to global markets, manufacturing productivity has continued to increase from 1987 to 1992. This is all happening with fewer people, more technology and changes in work processes (AICUM, 1991, Commission on Professionals in Science and technology, 1994, Reich, 1993, and Steeves, 1991).

The question that has to be asked is: Does this change in employer expectation in work design mean that only the brightest will be able to compete? Probably not.

Changes in work design will require that individuals have the prerequisite learning skills to understand, apply, and adapt to new technologies and evolving work processes. Additionally, individuals will need sufficient interpersonal skills to effectively collaborate with other team members who have been assembled to solve a client's problem. These individuals will need to bring a sufficient level of knowledge and experience to contribute to a firm's overall ability to create value and quality for its customers by efficiently using limited resources. Individuals will also need the cognitive skills to continuously learn on and off the job and develop the self-confidence to articulate a point of view, take calculated risks and make decisions. If organizations are to successfully compete in a global economy, they must attract a variety of people with differing skills, accomplishments, and a common interest to apply technological innovation and to anticipate and exceed customer needs. Overall success of individuals and the competing firms will be based on these abilities.

In the future, success of competing firms will be measured more in terms of continuous improvements rather than through the development of breakthrough technologies. To develop the necessary technical, professional, interpersonal, and continuous learning competencies, individuals must be capable of expanding their basic learning skills and utilize fundamental knowledge of mathematical and scientific inquiry (trigonometry, scientific method). Moreover, they must be able to think holistically and analytically, speak and write clearly, and effectively work with others. In addition to these skills, a positive attitude will be necessary to develop one's self-confidence, persistence in solving problems, adaptability in thinking about problem solutions, and a supportive attitude towards continuous learning. Collectively these skills will empower individuals to take risks and make decisions on the job (Miles, 1975).

Those individuals that have average intelligence are persistent problem solvers, have the ability to collaborate with others, can translate theories into innovative solutions will be able to compete in the technical workforce and workplace. Based on these individual characteristics and the synergy that is derived from well-directed and motivated people, organizations will also be able to successfully compete in the global economy (Blake, Mouton, and Allen, 1987 and Bridges, 1992).

The Next Generation Of Polytechnic Students

If we use the entering first grade class of 1993 as the reference point to this discussion, then the next twelve to twenty years of these potential graduates from the public high school systems in this country will continue to be less academically prepared for college-level work. Current demographic data suggests that the majority of this country's children will grow up in environments characterized as lower income (poverty-level or below) families, single parent households, "latch key children", with fewer role models to encourage them to study or think about careers after high school or even to encourage them to continue on to school (Astone and McLanahan, 1991, Fieerman, 1992, Futrell, 1993, Gerald and Hussar, 1991, and Marsh, 1990). Based on data published on literacy levels in this country (Mullis and Dossay, 1994), the high school diploma will not have much meaning in determining who will succeed in a college environment.

Faculty at the polytechnics already experience a bipolar distribution within student learning and success in the classroom. Although students enter the polytechnics with the same high school credentials as their predecessors (course titles and grades), about half of these new students lack a working familarity for the most basic learning skills needed for college level mathematics, reading comprehension, and writing skills. This is not to say that the K-12 education system will not produce academically prepared people for colleges in the future, but the numbers of these students will diminish. At present, there is too much inertia in the K-12 public school systems in this country to fundamentally change this projected outcome. (Futrell, 1993)

At best the polytechnics will continue to attract fewer well-qualified students to their classrooms. As a result, they will need to focus more on transitional years to prepare applicants for the rigors of college work such as transitional preparatory years utilizing a thirteenth grade or pre-engineering program. In addition to developing the basic learning skills an emphasis will also need to be placed on the development of competencies for continuous learning and developing the interpersonal and organizational skills for studying and learning on the job. This may require that those at the polytechnics proposing future curricular structure and pedagogy will have to recognize that special programs will not make up for twelve years of impoverished learning by themselves. For example, new curricular designs will require the flexibility to adapt and add educational value to those students who have the motivation and desire to develop the self-confidence to learn. At the polytechnics this issue of high school grade inflation, diminished academic preparation and learning will continue to develop into a greater obstacle (American Institute of

Architects, 1994, Astin,Korn and Riggs, 1993, and Reynolds and Oaxaca, 1988). In the near future, there will be more first generation college students coming to the polytechnics (going from about one-third today to one-half) who will need additional time to complete a four-year program (from five years on average today to about six years). Most students will need greater access to academic resources and advisors to learn how to learn so that they may become successful while in college and after they graduate.

The next generation of students coming to the polytechnics will also be less patient with current teaching styles since they will have lived in an environment that supported “instant gratification”, less interaction with others and a reliance on "show and tell" computer programs and television. It will take many years to raise the level of mathematics and scientific performance from sixteenth and eighteenth place when compared to other industrialized countries. Finally, attempts will have to be made to deal with children who have grown to accept lower expectations of themselves and their performance.

Because of the need by industry for qualified graduates from the polytechnics, the next generation of students coming to the schools will have to include more women, minorities, and other non-traditional students, such as those that may now be attracted to business programs. Overall, starting pay scales for graduates from the polytechnics still remain high when compared to other undergraduate programs. But phobias for mathematics and scientific inquiry will have to be overcome especially in the early schooling of students and before they reach high school. Contrary to myths about engineering and technology, a successful student does not have to be a genius in mathematics, but must be able to utilize some of the basic concepts in trigonometry, calculus and the sciences to solve technical problems.

A comparison of the prerequisite entry skills for careers in the technical workforce to the current and projected skills of the high school graduate shows there is a chasm that must be bridged by the polytechnics.

Foremost will be the need to raise expectations for individual learning and performance especially in the areas of basic learning skills, cognitive thinking, and technical knowledge. Emphasis will also be placed on developing and utilizing interpersonal skills to enhance the learning experience, putting competition into a perspective in which individuals and organizations can both win and developing the necessary skills to negotiate conflict in the work place and throughout one's life. Habits must be formed to learn and expand one's technical knowledge in order to remain flexible and adaptive to technological and organizational change (seeing many sides and approaches and different solutions to the same problem). Skills and the motivation to continue to learn and improve performance will be essential for people to compete in the growing global economy.

Evolutionary Changes In The Learning And Teaching Paradigm

When faculty had the brightest students coming into the classroom, much could be assumed about learning and teaching approaches at the polytechnics. When there were more students who wanted to put themselves through the polytechnic experience than there was space, polytechnic educators could focus more on their consulting or research than on understanding what it meant to be an instructor at the undergraduate level. Not only at the polytechnics but throughout higher education, educators are asking some very basic questions about their roles as teachers and researchers. There is an adequate body of information today that questions the effectiveness of current teaching approaches at the polytechnics and how they "fit" with students' learning strategies. In the past, it was enough to teach the standard practices of the profession to enable a graduate to go out into the job market and succeed (Reich, 1992). However, that was in a relatively constant environment that was controlled by a few nations who could establish the rules of trade and commerce. This is not true today. Therefore, new techniques are needed to motivate and involve students in their own learning and to sufficiently raise expectations for them so that it can happen.

Fortunately, educators at the polytechnics have finally begun to realize that students, whether they are academically prepared or not, are not as capable of absorbing or recalling new information as was expected in the past. Lectures, although convenient for the faculty member, have not helped students to seek out information or to learn to distinguish that which is important or valuable in solving problems. The technique of instructing and drilling students about problem types has not prepared them for the complex issues that they must deal with in industry, the changes in the technologies, or the different approaches to societal or business problems based on cultural values or financial reasons.

As a result, undergraduate educators are beginning to realize that the method of instruction needs to change to adapt to the students. As most technical people quickly discover in practice, the real problems in industry are generally not technical but have more to do with either antiquated work processes and the inability of the organization to utilize the creative talents assembled at their organization to empower individuals to help solve complex problems. As is sometimes the case in education, management styles and techniques are now being structured to deal with today's employee (Champ, 1995).

As intuitive learners, polytechnic students are able to grasp the more theoretical and complex dimensions of a problem when they can visualize the problem. This knowledge should assist faculty in developing learning strategies to help those students struggling to understand word problems in the theoretical and application courses. For example, a student studying material science or engineering could then construct physical representations through computer imaging of problems understudy. From this technology, the student could then better understand the problem and those factors impacting a solution. Through this visual model a student would then be able to test out a number of approaches using the technology instead of focusing only on one solution or technique (Tobias, 1992).

With a rediscovery and emphasis on experiential learning techniques, the faculty member can become more of an advocate and catalyst for the student's own learning. Acting as a role model and experienced problem-solver, the faculty member will need to act in the capacity of coach in encouraging students to attempt new processes and assist the student to understand what failed or succeeded in the learning process. Donald Schön described in his book <u>The Reflective Practitioner</u> (1983), a learning experience in which students will become better problem-solvers if they are exposed to and encouraged to think of different points of view as they developed a solution as opposed to the more traditional learning process at the polytechnics that requires recognition of problem types and applying known solutions. Thinking of a new solution can then lead to other approaches that can be brought to bear on future problems (thus adding to the concept of continuous improvements as a competitive edge in the marketplace).

Experiential learning reinforces the techniques first developed and used during apprenticeship learning. By reflecting on personal experiences, techniques of observation and reflection are brought into the learning experience to expand and stimulate a student's understanding of underlying principles and theories that can be re-applied creatively to new situations. By building with their hands and mind, the concept of "hands-on learning" can be expanded to include existing as well as new techniques in the professions. For example, tradition in architectural education is the use of design courses to develop critical thinking and application skills. Design courses are structured to help the student focus on self evaluation techniques. By asking critical questions regarding possible solutions, the student is required to integrate their previous experiences and knowledge into new solutions. This technique is also being applied to design courses in the engineering curriculum that were originally taught to students as having only one correct mathematical answer. In architecture, these initial courses utilize the student's previous experiences in manipulating two dimensional shapes and color to include an understanding of three dimensional space. Engineering students explore previous experiences from "tinkering" with mechanical, electrical or computer projects at home to exploring mathematical and computer technologies that are now applied to complex computer aided design projects in their disciplines.

Understanding the need to develop collaborative techniques to be competitive in today's global economy is also bringing to the polytechnics a different perspective on pedagogy, course content and the interdisciplinary nature of problem-solving. Presently, the polytechnics' primary approach to curricular structure and course content is sequential and reflects the techniques of problem-solving by yesterday's expert in the discipline. In this sequential approach, technical problems are made simple by eliminating many of the non-technical constraints to the problem such as costs, societal attitudes and preferences. The student's education focuses primarily on the development of expert knowledge, solving static problems with only one or two variables. They do not analyze complex problems as dynamic processes requiring many people with expert knowledge as well as a view to solving the problem that forces the practitioner to look outside their discipline and to work with others. This approach is starting to change, but it will probably take several generations of practitioners returning to education to completely transform this approach.

Cooperative education programs reinforce both the need for individuals to work together and the fact that complex social and technical problems already require many disciplines working together. Much of undergraduate education still reinforces the American ideal and value of individuality and personal creativity without adequate emphasis on teamwork. Many undergraduates are in a for a rude awakening as they enter the firm to discover that organizational values quickly replace individualism. Polytechnic graduates also come to realize that factors other than a competent technical solution might drive the direction in which they are to make a technical decision such as dollar limits or return on investment placed on the project by the client. Efficiency of time and minimization of lawsuits become driving forces to the technical solutions. Some of the more successful firms have come to address these problems creatively by being able to work with many disciplines involved in the problem-solving process. There are some bright signs in academe that these collaborative models can and do work to make graduates better technical problem solvers (Meade, 1992). For example, faculty from the disciplines in architecture, civil engineering, and construction are team teaching subjects such as design, methods and other cross discipline courses such as regional planning and cost control techniques.

Current changes being examined by the polytechnics include experiential and cooperative learning techniques. These models "fit" well with the academically-prepared student and also serve as a useful technique for developing the learning skills of the less-than-prepared student.

Experiential learning through its use of concrete examples and experience is a tool that can motivate students to learn, and is an opportunity to test solutions and understand why they worked or failed. It is also an experience in learning that demonstrates why many solutions to the same problem may be appropriate and thus enhance the students analytical approaches to problems. It is an opportunity for students to explore and seek out new theories or less familiar approaches to new problems. With less focus on lecture and more focus on application, the entering student's level of expectation can be raised. There is also a greater chance that more students will be retained as a result of this new focus. In a survey of women and minorities conducted by ASEE of those considering a career in the polytechnics, both groups indicated their preferences and motivation to learn through working with their hands and mind. From their activity of developing and in some cases constructing specific solutions for a problem, such as freshmen year design courses, a sense of self-confidence was developed and brought to the next level of curricular material.

Cooperative learning techniques can also help the less-than-prepared student by reinforcing a behavioral pattern for learning that encourages learning from one's peers. Too many high school graduates have not yet developed the self-confidence necessary for learning. Cooperative learning techniques give these students strategies for gaining control of the learning experience, creating small successes, and a system of networks to build success with other individuals. Each of these experiences reinforces later skills necessary in the workplace including an ability to communicate with others and to convert individual competitive styles for the good of the project (or client).

With a renewed focus on teaching and learning styles, the polytechnics will be in a better position to work with the less-than-prepared student coming from the high school, as well as provide a more meaningful educational experience for all the students that come to their schools. Pedagogies inherent with experiential learning and cooperative learning models are also better suited for the firms that require the polytechnic graduates because of the focus on interpersonal and continuous learning competencies. Through a balance of theoretical and pragmatic learning, graduates, overall, will be in a better situation to understand and apply current techniques used in professional practice. With an emphasis on holistic thinking and managing information, innovation is also possible in responding to the many new problem types that graduates are likely to be exposed to throughout their careers. By emphasizing continuous learning, students will remain flexible for the many changes that they will experience and be open to new ideas in the market place. Continuous learning and improvement will benefit the organizations as they also compete for clientele.

Future Bridges

To a large extent, many of the existing bridges previously reviewed will need to be maintained and possibly expanded to attract new people to the professions and meet their needs throughout their educational experience. For example, in order to recruit the non-traditional student to the polytechnic such as women and minorities, new common experiences other than “fixing” the car or operating power equipment will need to be discovered. But in addition to the bridges already discussed, some new bridges will be needed to address the changes in the work design, the new generation of students coming into the polytechnics and the incorporation of the experiential and cooperative learning models.

The first bridge needed is that of developing future educators for the polytechnics and developing expectations and performance reviews that will support quality undergraduate education. Traditionally, educators in the polytechnic programs come from the discipline in which they teach. In addition to bringing life experiences to the classroom, most rely on replicating teaching styles that they experienced as undergraduate or graduate students. With the changes in the entering cohorts, these styles will generally lead to greater frustration on the part of the instructor and the student. New criteria will need to be used when selecting undergraduate teachers at the polytechnics and to a larger degree they will need to reflect the changes in the industry. For example, polytechnic faculty will need to demonstrate their own ability to work with others in teaching the curriculum and perhaps team teach with those providing instruction in the “service courses.” Has the faculty member team taught, solved problems in industry with teams and led these teams? In addition to being technically competent, what perspectives does the faculty member bring to the learning experience? How will they prepare themselves for teaching students not well-prepared academically? Is their interest mostly in developing and researching techniques or should there be in the development of their students' interest and ability in the field? Are the faculty willing to learn a pedagogy that will assist the student?

In establishing academic standards and in administering faculty performance reviews, a new emphasis on quality undergraduate teaching is essential. This is not to say that creative activity, administrative service and professional development on the part of the faculty members are not necessary. But when the faculty devote a disproportionate amount of time to these traditional responsibilities then the needs of all students, especially the less-than-prepared student, are not being met. New pedagogical techniques that enhance student retention (building on a student's self-esteem and confidence), enhance experiential and cooperative learning models, or inspire students to invest more in their own education experience should be recognized as a higher priority. To this end, some faculty may be required to re-prioritize personal loyalties from the needs of their professions to those of the schools and their student's educational needs. For the polytechnics, this will probably mean a re-assessment of criteria used in faculty compensation, promotion, and tenure systems to emphasize instruction instead of research.

The second bridge is that of restructuring the faculty allegiances within the larger setting of the polytechnic and in particular the departmental organization. The current model of departmental structure was first introduced into this country in the early twentieth century by graduate schools who had modeled their own efforts after the German research universities . In addition to competing for limited resources at the university, a curricular structure was created based on the territorial rights of the stronger departments.

At the undergraduate level, departmental structures reinforce "turf issues" related to courses and teaching loads. At the polytechnics, they also reinforce sequential learning and discourage approaches to team teaching or interdepartmental sharing of resources for the same students that they are teaching. Since most of the professions associated with the polytechnics have already built the bridges to include a diverse group of people to solve technical problems, polytechnics are overdue in employing some of these same techniques or directions. For example, at the undergraduate level a team of faculty from different disciplines could be made responsible for directing a group of students in their curriculum instead of the traditional discipline departments. This would encourage the development of cross discipline skills and competencies now expected in the workforce. Examples of this are the number of environmental (civil and chemistry), computer engineering (electronics and computer science), electromechanical engineering (electrical and mechanical), industrial design (graphic design and manufacturing), facilities management (interior and mechanical), and construction management (architecture and construction) programs already offered at the polytechnics. In each case, faculty from different disciplines are required to teach and structure the curriculum so that students are able to learn and apply the principles from these disciplines.

A major concern at the polytechnics is the student's inability to effectively communicate through written and oral presentations the ideas that he or she has developed for a specific technical problem. By including jury members from non technical disciplines such as humanities, social sciences and management, students would also be evaluated on their presentation abilities in addition to the merits of the specific design solution. The value of this approach is that many technical people throughout their careers are required to present information to people outside the disciplines such as clients and community groups. Subject to the types of problems being explored, a jury might also comment on the effectiveness of the interdisciplinary problem solving process used by a group of students, their collective ability to solve a client's problem, and their ability to address societal concerns related to that problem and use of technology. By including non technical jury members on a design or capstone course, a student's ability to evaluate their communication and work-in-process effectiveness would be developed.

By encouraging faculty to develop design or technical problems that require students to draw from disciplines outside their own developing expertise, faculty could also develop goals for their own course outlines to incorporate issues related to a future practitioners ability to remain adaptive and flexible throughout their professional career and keep pace with changes in the industry, economy and technology. Specific examples would include team building exercises borrowed from the social sciences and management disciplines and experiments in utilizing problem solving techniques outside their own discipline such as qualitative research, critical thinking techniques, and cross discipline techniques now used in biomedical research.

By encouraging cross disciplinary approaches, in particular, from outside the technical disciplines, the quality of undergraduate teaching in the technical disciplines will also be enriched with examples that could better match a student's learning style with a faculty member(s) teaching styles. There will always be plenty of opportunities for faculty to remain active in their discipline through conferences, consulting and research. However, cross disciplinary approaches could force the faculty to focus on student learning and development as a more complete professional. This would in turn help faculty view themselves from the larger perspective of what it is to be an educator at the polytechnic and not simply as a faculty member in a department teaching their course.

A third bridge needed is one between the polytechnics and the program accreditors. Accreditation serves many purposes including that of raising expectations and quality for academic programs nationwide. Based on current efforts by federal and state governments to protect consumers from claims made by the educational institutions, program accreditors have focused on the minimum technical specifications for a program rather than on the expected performance of students for mastering certain learning and technical competencies. Polytechnic educators and the associated professional societies that contribute to the standards need to re-focus their attention on what it means to receive a baccalaureate degree based on the changes in the industry. Additionally, criteria or standards should not be written to assume that the student will learn everything in four or five years, and more importantly, that all learning will occur in the formal classroom. Frequently, course content is expanded with an assumption that more can be learned by less-prepared students and sometimes in a shorter period of time.

The fourth bridge required is that of work with those organizations that seek polytechnic graduates, including the graduate schools. There is an uneasy tension between the ploytechnics and the firms in agreeing upon the type and level of skill development expected of graduates. This is especially true when determing what skills are needed to be immediately employed by a firm and those skills that will help the graduate continuously learn and be productive in future years. Most employers want to hire a graduate who can be immediately productive, and who has the skills to remain flexible while learning the firm's current problem solving approaches.

This objective is difficult to achieve and generally not attainable given the learning distance that most polytechnics have to travel with their students in preparing them for the diversity of problem-solving techniques now used in industry. Cooperative work experiences are a good technique in exposing students to "real-life" situations and an opportunity for employers to look over a potential full-time employee. Unfortunately, even in the best situations, these experiences do not take full advantage of the learning potential that students have. A new attitude will need to be developed, perhaps similar to that in Germany, where it is expected that individual firms teach specific techniques and the polytechnics concentrate on the learning skills to make a future employee adaptive and flexible to developing new technologies and processes.

The responsibility for continuous learning then becomes a joint effort between the polytechnics, the student or employee and the employer. Potential articulations among employers could also lead to a swapping of practitioners and faculty for a short period of time, enabling the faculty member to acquire new experiences and for the practitioner to develop new skills in leading and training people on the job. There is presently inadequate collaboration among those who hire and those who train the future technical workforce. The potential value of internships, cooperative work experiences and project-related courses are too frequently seen as time fillers and not as an opportunity to learn from real problems and experiences as was the case with apprenticeship programs. The potential for this type of interchange could be that students would attempt to solve "real life" problems with technical assistance and resources from the companies that would directly benefit from this activity.

The fifth bridge is between the polytechnics and the K-12 schools. Like any good technical organization, there is a concern for both the raw materials and the suppliers. There is much that can be learned by the educator from the polytechnics in talking with the educators responsible for the development of children in grades K-12. A great deal of the literature regarding student problems with mathematics and science stems from a series of issues of instructor preparation and training, inappropriate pedagogy that bores students, lack of role models or mentors to encourage students to continue learning in this area, and a lack of instructional resources. This is where educators from the polytechnics, polytechnic students, and K-12 teachers could all benefit from closer working relationships that are not just directed at recruiting the best students to their programs. For example, polytechnic faculty have available resources (equipment, software, industrial contacts) that could be packaged, made into electronic instructional resources like CD-ROM to be brought into the classroom to support a particular teacher. Training in new techniques could also be made available at the polytechnics to K-12 teachers during summer sessions or development days. Students from the polytechnics could be available and earn credit by assisting as mentors or teaching aides in specific technical disciplines. There are a number of other possibilities, but the real issue is that significant changes at the K-12 levels will not occur without additional resources such as those that the polytechnics can provide. Given available federal funds, what is needed is a commitment from those in higher education to be involved and to be recognized for these efforts.

Conclusion

There are already a number of fundamental changes occurring in the workforce intended to make organizations more competitive in a global economy. Some of these changes are attitudinal, others are organizational, and still others question the basic precepts about how we do business. It is clear that for organizations based in the United States to be successful in the future they will need an educated workforce that will be up to these tasks. Unless we as a nation are willing to accept a continuing decline in the standard of living, and are prepared to become the low-paid labor force of the world we must solve this educational problem. Years of effort in developing a quality and accessable public educational system must not be abandoned. We must endeavor to renew our collective efforts to find ways to correct what is wrong with educating the K-12 students and find transitional solutions to prepare the graduates of the current system.

Most public high school students graduating in the 1990s are less prepared academically for studies at the polytechnics. However, this does not mean that the high school graduate is less intelligent than those that came to study at the polytechnics in the past. There are numerous reasons for this decline in academic preparation. Regardless of the reasons students, today, will be able to succeed if given the encouragement and support to achieve beyond their current personal educational and career expectations. At issue is whether or not the polytechnics and related industries can provide the leadership and solutions to address the needs of the new generation of students who will eventually be called upon to direct this nation's technological developments. It is clear that fulfilling this need is in the best interest of both the polytechnics and industries hiring the graduates. A start to correcting long term needs is to develop a number of transitional solutions or bridges as previously discussed in this chapter. Interestingly, and as developed in this dissertation, the transitional tools or bridges are already available. What is now needed is the will and energy to adapt and use these tools to address rather complex societal problems affecting and encouraging a student's learning ability. There is a special responsibility that we all have, especially those of us who have been fortunate to gain degrees beyond high school. In approaching this responsibility, we should not expect that there will be a single simple solution that will correct what has occurred over the past twenty years. As a nation we have shown historically that many people working together will make a difference.

This dissertation has described the ongoing changes in our technical workforce, the skills expected by employers, and the expected skills of students projected to graduate from the high schools in the future. There remains a widening gap for entering polytechnic students for learning and mastering a number of competencies needed to participate in the future workforce. This dissertation has also described a number of academic bridges that are currently being used and are at least partially successful. Additional bridges are needed if the polytechnics are to take full advantage of a new generation of students who will continue to come to their doors. Preparing these students by using transitional bridges previously outlined is possible. Committment and active participation from the polytechnics and other parts of society will also be needed if we are to collectively educate the future competitive workforce for a global economy.

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