Engineering Technology in a Liberal Arts University

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Bloomsburg University of Pennsylvania has a strong liberal arts tradition dating back to its founding in 1839, as Bloomsburg Literary Institute, a private academy to provide classical education. All students are required to complete over 50 semester hours of general education courses within the disciplines of arts and sciences. We have recently initiated a new Bachelor of Science degree in electrical and electronics engineering technology, a program unique in this liberal arts setting. In this paper, we will discuss how and why engineering technology was introduced into this type of environment.

The need of a new program
During the early 1990's, our faculty noticed that most graduates in physics, including some of the very best, were choosing to go to work immediately upon graduation, rather than continuing their education in graduate school. This was a significant departure from previous trends. In response, the department adjusted the physics program and academic advisement so that students bound for industry upon graduation would have a strong foundation in both electronics and in optics, two areas of application in which the department had strength in terms of faculty expertise and laboratory facilities. In addition, the department began making contacts with industry leaders to determine the characteristics of an effective applied physics program.

The Ben Franklin Technology Partnership is an agency of Pennsylvania government, set up to connect industries with colleges and universities for mutual benefit. The Ben Franklin Technology Center in Bethlehem was able to provide contacts for us in over twenty businesses in our region, mainly in the electronics field. With the support of our Dean of Arts and Sciences, we began making visits to electronic manufacturing facilities, an essential action in helping us to understand the issues faced by industries.

We explored with industry personnel, the need for varieties of academic subjects, including, optics, electronics, manufacturing technology, electrical machinery, controls, and nano-fabrication. Recognizing that we could not satisfy all of the needs of all constituents, we focused on those needs that transcended many businesses. Various different local industries desired to employ graduates skilled in electronics, three-phase electrical machinery, power distribution, manufacturing, and controls. They needed graduates who can write and speak well, who understand the economic and social implications of their business, and who are well trained in the latest technology - able to apply it during the first day on the job. We concluded that engineering technology graduates with specialized training in both electricity and electronics, could best help to serve the needs of many industries in our region.

There was some evidence of feasibility of an engineering technology program at Bloomsburg University. Much earlier, in 1983, the university had completed a technology feasibility study for the governor of Pennsylvania. The university identified engineering technology as one of three areas for which there was a need and that could be supported by the existing academic infrastructure. The report recommended a new college of engineering technology complete with a separate new building, a dean, support staff, and various academic departments. After that study was completed, an election brought about a change in state government. The new administration introduced different priorities, so the engineering technology proposal was not acted upon, and nearly forgotten.[1]

Planning the program

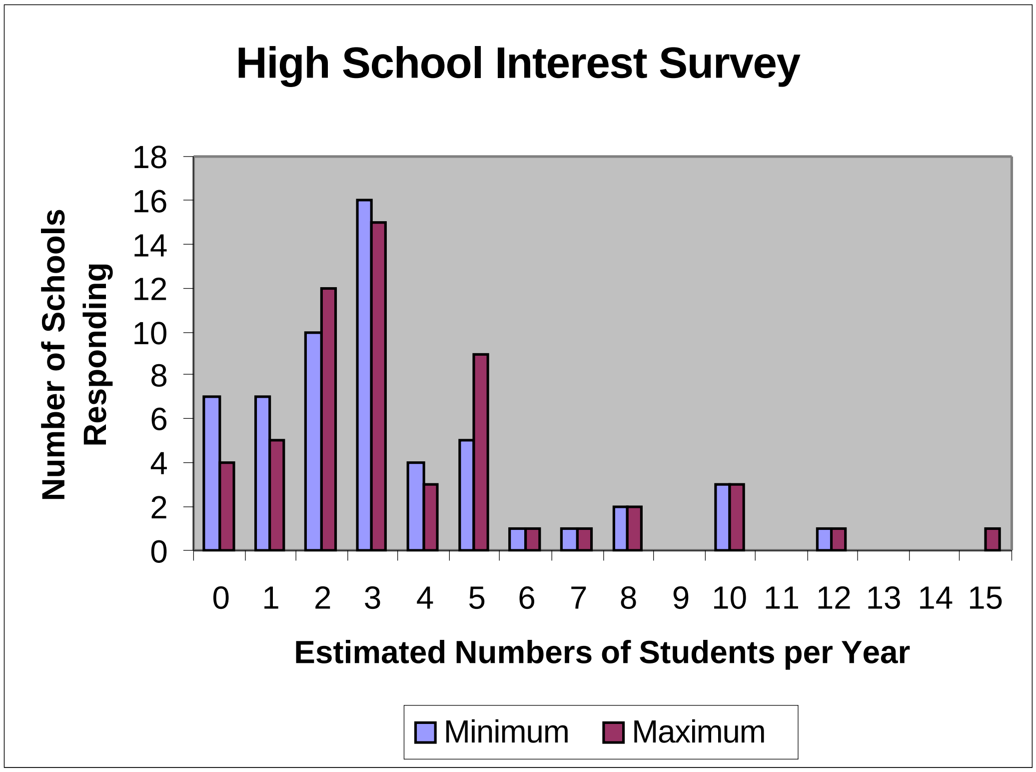
Recognizing the above perceived needs - the desires of some students to pursue vocational preparation, and the specific desires of local industry for qualified technologists - we began to seek background information in support of a program in electrical and electronics engineering technology. We needed the following:

1. Evidence for success in terms of numbers of students and strength of competing programs.
2. Sources of funding and estimated costs of the program.
3. Evidence of benefit to the university and society.
4. Evidence of consistency with the mission, priorities, and goals of the university.
5. A design of the academic program with the goal of accreditation.
6. Evidence of favorable employment prospects of students.

Population of Prospective Students

In order to obtain a measure of the level of interest among prospective students for our proposed program we conducted a survey of guidance counselors throughout the region from which Bloomsburg University regularly receives applications for admissions. Approximately 180 questionnaires were mailed to public school districts and to private high schools, and, of these, 57 were returned and analyzed. The questionnaires asked for an estimate of the number of students per year who would pursue a degree, such as, BS in Electrical and Electronics Engineering Technology.[2]

Results of this survey are presented in the graph shown below. Each respondent was asked to provide a single numerical estimate, although, many chose to offer a range of numbers. Therefore, we show both the minimum and maximum numbers in the graph. (If a respondent gave a range of from 2 to 4 students, then the number 2 is indicated as a minimum in the 2-student column, and the number 4 is indicated as a maximum in the 4-student column. A single numeric response, such as 3 students, is indicated as both a maximum and a minimum in the 3-student column. If a respondent gave no number, then, for analysis purposes, both a maximum and a minimum are indicated in the 0-student column.) [2]



Analysis of the data provided the following: Average minimum and maximum numbers are in the 3 to 4 range, while the most popular response is 3 students per year. There were a significant number of higher responses - many coming from larger school districts. The data suggest that the fifty-seven schools providing responses may contribute 190 to 210 seniors each year to the pool. If similar numbers apply to the 120 schools from which no responses were received, then the pool includes 590 to 680 students. If we recruit 25 students for the program, (less that 5% of 590 estimated minimum number) then it would be off to a healthy start. If that number could grow to 50 students per year (less than 9% of the pool) then the program as planned would reach maximum capacity. Five respondents to the survey provided very positive comments on the forms. They encouraged us to develop the program and to keep them informed. Thirteen additional respondents requested information in the form of brochures, posters, or faculty visits to their school classes. Three comments were negative.[2]

A Check of Nearby Programs

Four colleges and universities within Pennsylvania offer the Bachelor of Science in Electrical and/or Electronics Engineering Technology. They include Temple University, California University of Pennsylvania, Point Park College, and four regional campuses of Penn State. Enrollment data and graduation rates were obtained and examined for these institutions from the American Association of Engineering Educators and also from the Pennsylvania Department of Education. The data set was incomplete, though the most salient figure is that during the year 1997-98, all Pennsylvania colleges and universities graduated a total of 699 students in all areas of engineering technology - far less than the need for graduates that we discovered later. It appeared that engineering technology, in general, and electrical/electronics engineering technology, specifically, were receiving little or no emphasis in higher education of Pennsylvania.[3, 4]

Program Design

Our program was designed to both meet the needs of local industries and to achieve accreditation. To accomplish these, we strengthened our ties with industry leaders, some of whom we invited to join our new Advisory Board, and we sought advice from other members of the academic community. We participated in and contributed to a Northeastern Pennsylvania Electronics Initiative, sponsored by the Ben Franklin Technology Partnership, and we visited other campuses, including Rochester Institute of Technology.

We determined that the program should include two cooperative education experiences of seven months each (each one, a semester plus a summer). This feature provides students opportunity to gain experience in two organizations, and sufficient time to gain the trust of their cooperative employers and to accomplish meaningful work. Members of our advisory board overwhelmingly favored this structure. Our initial Program Completion Plan is shown in the table below. It includes eight semesters of academic studies plus two cooperative education experiences.

Program Completion Plan

This plan specifies courses to be taken by students each semester.

		Total Credits	Faculty Hours	Major Credits	New Faculty Hours	GE Credits
	Semester I, Fall					
58.180	Computer Aided Design & Engineering Graphics	3	3	3	0	0
58.141	Circuit Analysis (lecture/lab)	3	3	3	3	0
53.113	Precalculus (if needed)	3	3	0	0	0
52.115	Fundamentals of Inorganic Chemistry	4	6	0	0	4
20.101	Composition I	3	3	0	0	3
		16	18	6	3	7
	Semester II, Spring					
53.125	Analysis I	3	3	0	0	3
54.211	General Physics I	4	6	0	0	4
	Composition II or equivalent	3	3	0	0	3
	Group A or B elective	3	3	0	0	3
	Group A or B elective	3	3	0	0	3
		16	18	0	0	16
	Semester III, Fall					
58.221	Manufacturing Processes	4	6	4	6	0
53.126	Analysis II	3	3	0	0	3
54.212	General Physics II	4	6	4	0	0
56.121	Computer Science I (C++ language)	4	4	4	0	0
		15	19	12	6	3
	Semester IV, Spring					
54.315	Electronics (Analog)	4	6	4	0	0
53.225	Analysis III	3	3	0	0	3
58.231	Electric Power & Machinery	4	6	4	6	0
	Group A or B elective	3	3	0	0	3
	Group A or B elective	3	3	0	0	3
		17	21	8	6	9
	Semester V, Fall					
54.316	Digital Electronics	3	3	3	0	0
58.323	Quality Control & Experimental Design	3	3	3	3	0
53.322	Differential Equations	3	3	3	0	0
58.300	Career Orientation	1	1	1	1	0
	Technical Writing or Public Speaking	3	3	0	0	3
	Values, Ethics & Responsible Decision Making	3	3	0	0	3
	Fitness & Recreation Skills	1	3	0	0	1
		17	19	10	4	7

		Total Credits	Faculty Hours	Major Credits	New Faculty Hours	GE Credits
	Semester VI, Spring - Summer					
58.380	Cooperative Education in Industry I	0	0	0	0	0
	Semester VII, Fall					
58.331	Linear Systems and Signals	3	3	3	3	0
58.341	Instrumentation & Control	4	6	4	6	0
	Group A or B elective	3	3	0	0	3
	Group A or B elective	3	3	0	0	3
	Fitness & Recreation Skills	1	3	0	0	1
		14	18	7	9	7
	Semester VIII, Spring					
54.317	Microprocessor (Computer) Electronics	3	3	3	0	0
58.421	Seminar: Problems and Applications I	1	1	1	1	0
58.441	Communications Principles	3	3	3	3	0
	Group A or B elective	3	3	0	0	3
	Free Elective	3	3	0	0	0
	Free Elective	3	3	0	0	0
		16	16	7	4	3
	Semester IX, Summer - Fall					
58.480	Cooperative Education in Industry II	0	0	0	0	0
	Semester X, Spring					
58.451	Electronic Filters	3	3	3	3	0
58.422	Seminar: Problems and Applications II	1	1	1	1	0
58.461	Radio Frequency Effects and Measurements	4	6	4	6	0
	Group A or B elective	3	3	0	0	3
	Free Elective	3	3	0	0	0
	Free Elective	2	2	0	0	0
	Fitness & Recreation Skills	1	3	0	0	1
		17	21	8	10	4
	Totals	**128**	**150**	**58**	**42**	**56**
	Fall	62	74	35	22	24
	Spring	66	76	23	20	32

Since receiving program approval from the System in April 2000, minor changes to the originally approved curriculum (shown in the table) were incorporated during the Spring-2001 to make the program more effective. The total numbers of faculty hours and student credit hours were kept unchanged to avoid administrative delay. Some of the changes are:

- A one-credit "Introduction to EEET" course was introduced for all incoming freshmen in the program. The goal of this orientation course is to establish a direct link with the students starting from the very first semester in campus. This course covers study skills, introduction to the engineering technology curriculum and profession, engineering topic research and presentation, invited lectures by engineers/technologists from local industries, and field trip to area electronics manufacturing industries. The effectiveness of this course on student retention will be studied.
- The 3-credit/3-hour Circuit Analysis course originally planned for fall offering was changed to a 4-credit/6-hours course with a full three-hour laboratory for offering during the spring semester of the freshman year. Delaying this course by a semester provides an opportunity for entering students to catch-up with their math and writing skills. Also, a full three-hour lab makes this course more effective for students since this is their first major technical course.
- The 4-credits "Instrumentation and Control" course was expanded into two 3-credits courses to cover Instrumentation and Control topics in more depth. This was needed due to the concentration of control system integrators in the area.
- Two 1-credit seminar courses were dropped since it was felt that the mandatory two seven-month long co-op experiences make these courses redundant.
- Minor changes were made to other courses to make sure the total faculty and student hours are not altered to the originally approved program. All of the curriculum changes were incorporated upon discussion and concurrence with the active Industrial Advisory Board of the program.

Future ABET Accreditation

The first batch of students joined the program in Fall-2001; accordingly, the first batch of graduates is expected in Spring-2006. We are working towards an initial evaluation visit by ABET-TAC in Fall-2006 under Technology Criteria 2000 (TC2K). The baccalaureate program is designed to be accreditable per TC2K guidelines for program criteria and characteristics, faculty, facilities, institutional and external support, and assessment. The total credit, communications, mathematics, physical and natural sciences, social sciences and humanities, and technical content requirements per TC2K guidelines are incorporated in the curriculum design. A capstone design experience is not built into the curriculum; however, 14-months of full-time co-op experience and upper level design-oriented courses will most likely suffice the intent of this requirement. The project management techniques, statistics/probability, transform methods, and applied differential equations are part of the curriculum satisfying the TC2K requirements. A pre-accreditation visit is in the plan for Spring-2006. Faculty members dedicated to the EEET program will receive training on ABET accreditation process through participation in ABET and ASEE sponsored seminars. A couple of schools with accredited programs under TC2K criteria will be visited to ensure that the designed program exceeds ABET-TAC requirements for a successful accreditation.

Consistency with the Mission, Priorities, and Goals of the University

A real concern among our liberal arts colleagues was whether the new program would benefit and be consistent with our strong liberal arts traditions. Some faculty members fretted over whether engineering technology would be the first step in transforming a respected liberal arts university into a vocational trade school. We reminded the faculty that the general education requirements would still apply to engineering technology students along with the rest of the student body. Furthermore, because of the desire within the business community for technologists able to communicate well and understand the social and economic context of their work, the general education requirement is recognized as a pillar of the program, rather than an appendage.

Many academics outside of technical fields do not understand the discipline of engineering technology. Thus, we found it necessary to explain the nature of this profession. The best description we found is from the Engineering Liaison Committee of the State of California.

> "Engineering Technologists are graduates of bachelor-level programs in engineering technology. They apply engineering and scientific knowledge combined with technical skills to support engineering activities. Their areas of interest and education are typically application oriented, while being somewhat less theoretically and mathematically oriented than their engineering counterparts. They typically concentrate their activities on applied design using current engineering practices. Technologists play key roles on the engineering team; they are typically involved in product development, manufacturing, product assurance, sales, and program management." [5]

We specified our program justification and goals as follows: *Engineering technologists have become salient members of the engineering teams used in modern industry. Experienced in the application of the various modern devices and machines used in manufacturing processes, engineering technologists are prepared to take responsibility for finding technical solutions to the day to day problems encountered in an industrial setting. Our Electrical and Electronics Engineering Technology Program will focus on the electrical and electronics specialty and will provide the education of engineering technologists including the hands-on laboratory experiences using the specific types of equipment found in modern industries.*

Our proposal is consistent with our university Mission Statement because it was specifically designed to help meet the needs of the business community, and it extends the academic environment beyond the classroom. By challenging students with both academic and real industrial problems and by requiring them to produce both oral and written reports of their findings and solutions, we expected to develop in them the characteristics specified within the Mission Statement.[6]

The Priority Strategic Goals and Directions of the university are well served by the implementation of engineering technology. Benefits of the program include the involvement of external constituencies, assisting students toward specific careers, attracting talented, academically oriented students, provision for capstone experiences for students, and allowing students to learn using state-of-the-art technologies directly applicable to their chosen fields of study. All of these were specified in the strategic plans and were recognizable by faculty and staff members who had worked on the planning documents.

Benefits to the University and Infrastructure Support

The academic infrastructure of the university is well equipped to both support and benefit from a new program in engineering technology. The faculties in the disciplines of mathematics, computer science, physics, and chemistry are able to contribute technical expertise and staffing for many courses needed by students in the new major. In addition, incoming students provided added populations to technical courses already offered in these disciplines. The numbers of new students made it possible to increase the frequency of offerings of some courses, making it easier for student to schedule them.

Economic Need for the Program

Engineering technology can be justified with the perspective of statewide and national economies. We used information provided by the American Electronics Association and by the Commonwealth of Pennsylvania (circa 1998). In the paragraphs that follow, each of these will be discussed in turn.

National Economic Perspective

The high technology portion of the American economy is huge, and it is growing at an ever-increasing rate. It employs more people in manufacturing than any other and offers wages 77% larger than the average wage in the private sector (1998 figures). The average wage in the high-tech sector is almost $20,000 per year greater than wages in traditional sectors (roughly $45,000 vs. $25,000). Starting salaries for professionals in demand are in the $40,000 range and rise very quickly. High-tech jobs account for 20-25% of real wage and salary growth. In terms of sales, it is the single largest industry and the largest merchandise exporter. The $450 billion market value of Silicon Valley's publicly traded high-tech companies is nearly as great as the entire French stock market. The production of electronics related devices and services, comprises 6.2 % of the Gross Domestic Product, compared with 4.3% for automobile manufacturing and services, 3.7% for construction, and 1.9% for chemical manufacturing. In the three-year period 1993 to 1996, U. S. spending on high-technology items totaled $420 billion, $280 billion of which was on hardware investments in information technologies (telecommunications, computers, etc.). To put these numbers in perspective, $280 billion is 17% greater than U. S. new motor vehicle purchases during the same time period, it is 49% greater than spending on new homes, and 168% more than that spent on commercial and industrial construction.[8,9,10]

In terms of scientific and engineering achievement, this state of affairs did not happen instantly. Fifty years have passed since the invention of the transistor, thirty years since the development of the integrated circuit, and twenty years since the first personal computers. However, the technological evolution and societal change have produced exponential growth in the high tech industry. In 1990, the United States sold $77 billion worth of high-tech goods abroad, but by 1996, this figure exceeded $150 billion, nearly double in six years! In the five-year period 1993 to 1998, the number of high-tech jobs increased from 3.8 million to 4.8 million, up 26%. In the three years preceding 1998, the high-tech sectors contributed 27% of the growth of the Gross Domestic Product, while in the preceding four years, the production of computers and semiconductors alone have been responsible for 45% of U. S. industrial growth. In order to maintain these growth levels, the U. S. needs to adjust its investment in education as well as in research and development.[8,9,10]

Pennsylvania Economic Perspective

In Pennsylvania, agriculture is the largest industry. The average high-tech worker earns $46,872, or 58% above peers elsewhere in the private sector. Just as elsewhere in the U. S., the number of such workers has grown at an increasing rate. In the seven-year period from 1990 to 1997, Pennsylvania's high-tech work force increased by 17,900 workers, yet 8,600, or nearly half, of these were added in the single last year of the seven-year period.[9]

Such growth cannot be sustained without an increasing supply of well-educated, technically knowledgeable workers. In order to attract workers with appropriate skills, industry has increased salaries and wages by 12% (adjusted for inflation) in the 1990 to 1997 period. (The real dollar increase is greater.) Indeed, within Pennsylvania, the number one concern of the high-tech industry leadership has become workforce quality and development.[9,10]

In Technology 21, a study undertaken for the Ridge administration (Tom Ridge, Governor of Pennsylvania), high-tech industry executives have recommended that industry, educators and service providers join together to promote and provide work force development; specifically to fill gaps in technical skills of the existing workforce, and to provide for a continuous supply of technically knowledgeable and skilled workers. To this end, they recommended that the Commonwealth should foster and strengthen business and education partnerships including the development of internships and mentoring programs. Such efforts to provide a competent workforce for the high-tech industry would offer benefits to other sectors in Pennsylvania's economy. An employment multiplier refers to the number of jobs created in other parts of the economy for every job at a particular business. In traditional industries the multipliers range from 1.5 to 2.0, yet Microsoft's multiplier is reported to be 6.7. Such elevated multipliers are typical in the high-tech sector, because of the inherent productivity found in this type of industry.[10]

The Role of Technology in the Economy

Single important discoveries or inventions lead to breakthrough technologies, technological revolutions that depend on these discoveries. Such discoveries of the twentieth century include the transistor, the laser, the high T_c superconductor, the magnetron, and the charge-coupled device. These inventions by research scientists became the basis for profound technological advancement. However, in recent years a new technology development paradigm has emerged. This relies on the continuous improvement of technology brought on by a myriad of lesser inventions and ideas rather than the single "breakthrough." Thus by gradual steady improvement of fabrication techniques the number of components that can be incorporated into integrated circuits has increased exponentially for 30 years, while the power requirements and costs of such circuits have decreased. This form of technological advancement, by continuous improvement of manufacturing, of product development, and of new applications, relies as much on the skills of many engineering technologists and technician-level workers as on the creative powers of the few Ph.D. research scientists. The technical intricacies of new products will place demands on the skills and knowledge of technologists, who will be responsible for their development, manufacture, quality assurance, and sales. Thus, the new technology development paradigm requires a large number of knowledgeable engineering technologists.[10]

Employment Prospects for Graduates within Pennsylvania

It is hazardous to assign a number to specific kinds of jobs that will become available a half-decade hence. With a focus on education rather than simply training, we shall attempt to prepare graduates to face the many technological changes of the future. Present indicators are that electrical and electronics engineering technologists have a bright future in Pennsylvania. The Department of Community and Economic Development reports that the state now has a shortage of 8,000 to 10,000 skilled technology workers. We have found that a variety of employers, some large some small have expressed needs specifically for electrical engineering technologists. Of course, these jobs will eventually be filled, so by 2006 graduates will depend on new opportunities. Based on present trends, there is no reason to doubt that they will be there.[11]

Financial Challenges

Our proposal called for the addition of two faculty members to the staff, two new laboratories, and large quantities of specialized equipment. A major complaint of the liberal arts faculty was the high cost of the program and the anticipation that money would be taken from meager budgets to support this expensive program. Committees are reluctant to grant program approval until evidence of funding is provided. At the same time, granting agencies and foundations require evidence of institutional support before providing funds. We were in a "Catch-22:" you can't get approval without the money, and you can't get the money without approval. Therefore, grants and loans were sought at the same time as concept and curriculum approval. Gradually, as the proposal moved from committee to committee, we were able to show evidence of applications for funds, then strong likelihood that we would receive funds, then finally approval of a grant and a loan.

We received both a grant and a loan from the Commonwealth of Pennsylvania. The grant, in the amount of over $350,000 was obtained through Pennsylvania's Link-to-Learn program to promote the use of computers in academic settings. In addition to our grant, we were able to secure a Venture Capital Loan in the amount of $250,000 from the Pennsylvania State System of Higher Education. Half of this loan will be forgiven provided that we achieve certain enrollment goals at the beginning of the third year of the program. (We are well on our way to achieving that objective.)

The projected budget for the first five years of the program is presented in the table shown below. Included, as line items are salaries of two faculty members, equipment costs, renovation funds for two new laboratories, and industry related activities for students. Two engineering technologists, in addition to the original staff, are necessary to achieve accreditation. Each year these technologists will provide 42 hours of instruction. In addition, one receives one-quarter release time (three hours per semester) for coordination activities. These activities include travel to industrial sites in order to maintain a close association with industrial organizations.

On-site visits are necessary to promote opportunities for cooperative education. Also, engineering technologists and other experts from industrial organizations are invited to campus to share their expertise with students and faculty as a standard practice in courses and seminars in the program. The budget also shows a requirement to purchase specialized equipment to begin the program. An annual operating budget for educational supplies to support all of the myriad activities associated with laboratory courses and travel to maintain close ties with members of the industrial advisory board, and other cooperating businesses. Funding is required for visits by the Accreditation Board for Engineering and Technology. Members of the Industrial Advisory Board have committed to special activities related to their involvement. Finally, two instructional laboratories must be renovated for use.

Five-Year Budget Projection					
Salaries & benefits [1]	Year 1	Year 2	Year 3	Year 4	Year 5
1st Engineering Technologist	75,676	66,540	69,867	73,360	77,028
2nd Engineering Technologist	0	0	62,431	65,553	68,830
Equipment [2]					
Equipment	550,714	150,800	0	20,000	21,000
Expendables					
Travel	3,000	3,150	3,308	3,473	3,647
Supplies	6,000	6,300	6,615	6,946	7,293
Preaccreditation & Accreditation Visits	0	0	5,000	0	10,000
Industry Related Activities [3]					
	34,188	34,188	34,188	34,188	34,188
Space and Facilities					
Electronics Laboratory Renovation	45,000	0	0	0	0
Manufacturing Laboratory Renovation	55,000	0	0	0	0
Totals	669,578	260,978	181,409	203,520	221,986

1. First year includes full-time summer work to initiate the program. Figures are set by CBA. Positions are available within the College of Arts & Sciences. Approximately, $75,000 in personnel costs will be covered by a Link-to-Learn grant and Venture Capital.
2. Equipment budget will be supported by Academic Enhancement Fees, Link to Learn grant, and Venture Capital Allocation. (Grant and Allocation have been approved.)
3. Activities will be provided at no cost to the university by participating industries.

Success

This year, 2001-2002, we have a thriving freshman class of 27 students.

Acknowledgements
Members of our industrial advisory board and other business leaders supported our work from the initial concept through all of the hurdles to the final system approval. We are most grateful for support from Primus Technologies Corporation, Litton Electron Devices Division, Advanced Electrical Concepts, Inc., and JPM Corporation.

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