Engineering Technology Education: A National Picture

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Abstract

Engineering technology (ET) programs across the nation have been experiencing declining enrollment, population shifts, image problems, and an influx of students with increasingly weakened academic skill sets necessary for achievement. The following is a summary of ET education across the nation and factors that have affected it during the last four decades. Initially, a number of organizations did parallel, independent studies to search for underlying causes. Based on their respective findings, a summary of recommendations is provided that is intended to strengthen ET programs, increase student retention and program satisfaction, provide better access to baccalaureate programs, and ultimately, transition to the workforce.

Kepner-Tregoe

During the last few years, two organizations, in particular, have been actively researching the state of ET in an attempt to understand and lay cause to problems associated with ET. During a two-day retreat of the Ohio Engineering Technology Educators Council, Ray Lepore, Dean of Math, Engineering Technology, and Business and Industry at Edison State Community College, led the Council through a Kepner-Tregoe (KT) [1] exercise to pull together thoughts and hypotheses to focus the group on the direction of the research project. The result was the identification of the following specific problems:

1) ET programs have visibility and image challenges.
2) ET programs have stagnant or declining enrollments.
3) ET programs have increasing competition for students from other adult education institutions, for-profit schools, and industrial vendor training.
4) ET programs struggle with maintaining contemporary and relevant technology, equipment, and instructors.
5) ET programs are receiving incoming students with increasingly weakened academic skill sets necessary for achievement.

The Council has also worked with another organization—the Maricopa Advanced Technology Education Center (MATEC)—established by the National Science Foundation to promote the development of a world-class workforce. MATEC is the worldwide leader in education and industry collaboration and is providing a parallel study of the ET problem, with a focus on the field of semiconductor manufacturing technology education. As the nation looks to its economic future, it must view a vibrant economy secured through a technically competent workforce as a major priority. Successful ET training will help us achieve that goal. Yet, if the number of appropriately trained graduates for such in-demand ET fields is stagnant or declining, it can be expected that technological competitiveness will likewise stagnate or decline. This paper is designed to communicate this Council's findings and promote efforts to improve ET program enrollments.

While completing the KT exercise, the Council hypothesized that one or more global events caused a downturn in the number of students entering legacy ET programs sometime between the late 1970s and mid 1980s. Legacy programs include electrical and electronic engineering technology (EET), mechanical engineering technology (MET), and civil engineering technology (CET). The following literature review includes summaries of national events leading up to and occurring during this period. This review also includes specific sections related to enrollment trends, state/federal funding, trends among high school seniors, FTE, employment, and the economy.

Enrollment Trends

The historical focus of vocational education was to prepare students for entry-level jobs in occupations requiring less than a baccalaureate degree. However, in the 1980s and 1990s, this focus shifted toward a broader definition of preparation, one that included not only point-of-employment vocational skills but also academic and technical skills to be used for cross-training for a broader range of jobs; this newer image also sported a new name—engineering technology. A possible consequence of this shift was the general decline in the participation of high school students in vocational education, along with a doubling of students entering health care, technology, and communication fields [2].

There are many reasons why prospective students may be steering away from traditional ET programs, but if the total number of students entering college declines, with all other factors being equal, then it should follow that virtually all programs should experience declines. According to a study by the National Center for Educational Statistics (NCES), by 1975, all age groups showed a downward trend in enrollment, except the 22–24 year olds, whose numbers increased only slightly. However, as indicated in Figure 1, enrollment by students 22 years old and younger decreased sharply from approximately 1980 until 1985. When reviewing specific programs, gender, race, and socio-economic status, similar patterns of enrollment declines were seen [3].

In vocational programs, general enrollment increased slightly until approximately 1980 when it began falling dramatically. Females reflected a slight drop between 1972 and 1980, but then saw a sharp decline (from about 25.7 percent to 12.1 percent) after 1980. Blacks, once representing more than 33 percent of the enrollment in vocational programs,

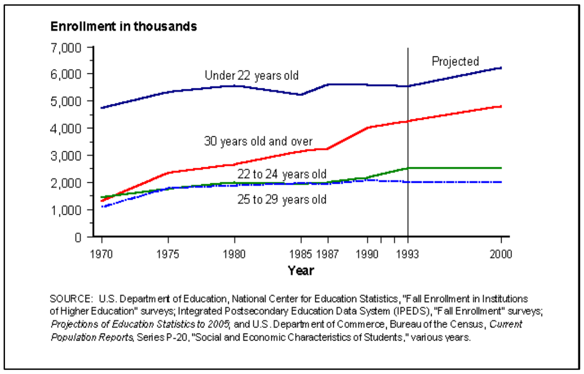

Figure 1
Enrollment in institutions of higher education,
by age: Fall 1970 to fall 2000

also plummeted to approximately 17 percent by 1992. Whites increased their numbers between 1972 and 1980, but then, too, dropped off from 20.8 percent to 11.4 percent.

In general, the fields of science, mathematics, engineering, and technology (SMET) suffered from the stigma of being predominantly white and male. Studies by the Higher Education Research Institute (HERI) at UCLA in the 1980s indicated a 20-year decline for women in science, math, and engineering (SME), despite enhanced recruitment efforts [4]. It should be noted that prior to 1996, none of the studies specifically included technology majors, nor was there mention of this disciplinary group in research projects or issue papers. Thus, prior to that date, SME, rather than SMET, was an appropriate descriptor. The addition represents yet another shift in focus. Nationally, persistence rates for women were approximately 10 percentage points lower than their male counterparts [5]. High attrition rates in SME programs were also seen for Hispanics, African Americans, and Native Americans, where only one-third of the Hispanics and one-half of the other two groups graduated from those programs [6]. Furthermore, only 37 percent of non-white students entering SME programs graduated, compared with 68 percent for white students [7].

National concerns about such under-representation generated a movement to recruit more non-white college students. By the early 1990s, the National Science Foundation spent more than $1.5 billion on recruitment efforts, with the National Institutes of Health following closely with $675 million [8]. Fruits of these efforts to fix the problem, however, came only in the form of new non-white students entering SME programs; attrition rates remained relatively unchanged [9, 10, 11, 12].

The Commission on Engineering and Technical Systems also made reference to problems with enrollment in ET programs, stating that while "programs designed primarily as the first two years of engineering education are reasonably well defined…problems of definition exist for programs in engineering technology and industrial technology" [13]. Such issues of definition can cause confusion in the categorization and reporting of enrollments. We are not suggesting that image and program definition alone account for the enrollment woes of ET; rather we are suggesting that being aware of a public shift in sentiment—regardless of the origin—can cause ripple effects in enrollment. Taking a pro-active approach to dealing with potential image problems can mean stability, if not growth, for ET programs.

Nationwide, a number of trends can be observed specifically related to enrollment in the 1970s and 1980s:

- By 1975, enrollment in higher education for all first-time freshmen—even when considering specific programs, gender, race, and socio-economic status—showed a downward trend.
- Historically, the focus of vocational education was to prepare students for entry-level jobs. In the 1980s and 1990s, however, the focus shifted to a broader definition of "preparation" and was renamed "engineering technology."
- In general, SMET fields were stigmatized as predominantly white and male. Despite national recruitment efforts to attract non-whites and females, attrition rates for those groups remained relatively unchanged.
- Attrition rates for all SME students, between their freshman and senior college year, were approximately 40 percent.
- Studies indicated that there were "problems of definition" for existing programs in ET and industrial technology.
- FTE seemed to follow patterns in enrollment changes.

Revenue
When looking at general funding for institutions of higher education (see Figure 2), there also seems to be a trend of reduced funding during the period in question (the late 1970s through the 1980s). Between 1960 and 1970, federal funds to institutions of higher education increased moderately at approximately 4 percent per year. Then, in the 1970s, funding increased by more than 10 percent per year. These major yearly increases turned into declines by 1977, though funding did start to increase again after that [3].

U.S. Department of Education outlays (1980–1995) to college students decreased by approximately 35 percent to postsecondary educational institutions and approximately 20 percent to institutions of higher education. Federal on-budget funds for postsecondary education increased rapidly until 1975 and showed moderate declines until 1982, when declines sharpened. Also from Figure 2, we see that outlays to elementary and secondary schools showed a similar pattern, except that this slowdown started in 1970 with sharp declines around 1980 [3].

Average (full) professor salaries at public institutions fell from $64,200 in 1972 to $49,500 in 1981 (in constant 1993 dollars), then rose back to $58,300 by 1992. While total revenue for higher education, with the exception of public two-year colleges, increased between 1980 and 1992, government resources fell in public four-year colleges

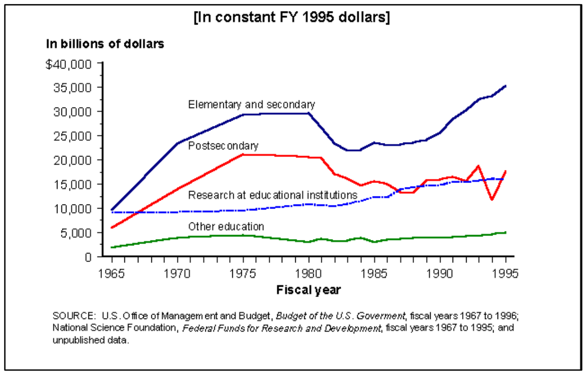

Figure 2
Federal on-budget funds for education, by level
or other educational purpose: 1965 to 1995

from $7,600 to $6,500 per FTE student and from 67 percent to 55 percent of total revenue [14].

Revenue per FTE Student (in constant 1994 dollars)				
Public universities:	1980:	$15,081	1992:	$16,931
Public two-year colleges:		$ 5,790		$ 5,743

> A possible reason for the rise in the cost of higher education over the long-term is a lack of increase in productivity in higher education. Whereas many sectors of the U.S. economy, particularly manufacturing and agriculture, have used technology and innovation to either increase the quantity or quality of goods provided with no corresponding increases in resources used, higher education is still provided in largely the same way it was when the nation was founded. When productivity growth in a particular sector of the economy lags behind that in the rest of the economy, the cost of providing that good or service increases [14].

Trends among High-School Seniors

Changes in family structure have been evident throughout the period from 1972 to 1992. The number of households composed of a married couple with children under the age of 18 declined slightly. At the same time, the number of single-parent households increased dramatically. In 1970, there were 2.9 million female-headed households with children under 18. In 1991, that number more than doubled to more than 6.8 million. Male-headed households with children under 18 increased from 0.34 million to approximately 1.2 million [15].

And while there is no direct link between demographics/family values and enrollment in traditional ET programs, there are notable changes in these factors during the period in question. As noted above, family demographics changed dramatically over this period. Also seen were value shifts. For example, in the 1970s, seniors in high school felt that "giving children a better opportunity," "living close to parents," "steady work," "success in work," and "money" were all either not very important or quite unimportant values. In the 1980s and 1990s, though, these same values were rated between somewhat important and very important.

Whether or not these demographics and value shifts affected high school students' choices or ability to do well in college is unclear. However, it is potentially another factor affecting the subsequent shift in student attendance rates and willingness to go to college.

Employment, Education, and the Economy

In the studies from which data have been gleaned for analysis here, it should be noted that trends stated or implied may be ambiguous because 1) data does not, in every case, include all schools offering these programs, and these same schools may or may not report data in every year; and, 2) firm definitions of programs that should be reported as part of traditional or legacy programs versus the newer niche or specialty programs are either different for different schools or are still evolving and, thus, are not necessarily consistent from year to year, even within particular institutions.

Another potential cause for a decrease in traditional ET enrollment might be a market shift. Coupled with a marked decline in U.S. exports in the late 1970s and early 1980s, the U.S. market shifted to focus on the PC and networking business and industry. At the same time, students began to abandon electronics to ride the wave of the PC industry's success [16]. Jobs were plentiful, and certification offered big bucks not attainable as an electronics technician. Many schools added new PC departments, while others added PCs to electronics. In the end, PCs dominated to the extent that electronics departments became computer (and electronics) technology departments. Adding insult to injury, electronics programs still surviving and unwilling to adapt ended up training students for technician jobs that no longer existed.

Part of the problem may also be a shift in image related to the shift in jobs. A major shift in employment in science and engineering fields between 1950 and 1990 likely also had an effect on the image of technicians in all of the engineering and technology fields. Science and technology employment, starting from almost nothing in the late 1940s, increased rapidly between 1950 and 1982—likely fueled by the introduction of the United States/Soviet Union space race, consumer electronics, and PCs [16].

Unemployment across the nation dropped to slightly more than 5 percent in the late 1980s before heading back to approximately 8 percent around 1992. It is interesting to note that annual growth for technicians exceeded that for engineers until the mid 1980s. Then, while both groups experienced a decline, technicians actually saw negative growth starting around 1988 [17]. It can be surmised that the term "electronics technician" started to be used less and less often, being replaced by terms such as field-service technician, engineer, manufacturing technician, and maintenance technician. Combining the negative growth rate of technicians with the reduced funding to educational institutions, it could also be the case that schools stopped marketing their traditional or legacy technician programs.

Now consider such a drop in program promotion at two and four-year schools with the current aggressive marketing tactics of proprietary schools, and it is easy to see how the current shift is possible. In spite of employment woes for technicians and declining enrollment in college and university legacy ET programs, proprietary schools continue to attract new students. So, here we see a picture of low unemployment (in the early to mid-1980s) and declining enrollment in schools and universities. Whether or not there is a correlation, we cannot say. Regardless, whether students are choosing the workforce over school due to plentiful job opportunities or choosing not to pursue an (advanced) education due to a poor image in the technology field, the end result was the same.

In 1967, when baccalaureate institutions first started accrediting ET programs, two-year institutions were already 20 years ahead of them with 193 accredited programs at 61 institutions. According to the Commission on Engineering and Technical Systems [13], by 1983, four-year schools were offering 271 ET programs, while two-year programs offered 460. A study by Hull [18] points us to the country's community and technical colleges as they are uniquely and ideally positioned to provide this postsecondary education and training that is essential if the United States is to maintain and advance its position as an economic leader in high-tech manufacturing. Interpreting these results, most programs have experienced losses in their traditional or legacy programs; while at the same time, many are showing promising numbers in their newer programs.

Engineering Technology Graduation and Enrollment Trends
According to the National Science Board's (NSB) Science and Engineering Indicators 2006 (see Figure 3), ET associate's degree graduates steadily decreased from 51,579 to 31,557 between 1985 and 2002 [19].

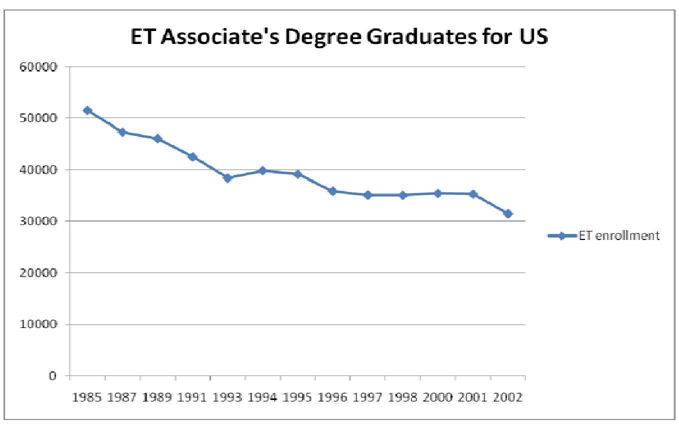

Figure 3
ET Associate Degree Graduates for the United States: 1985 to 2002

During this time period, U.S. two-year public colleges witnessed ET graduates drop approximately 39 percent. However, a survey of ET graduates does not tell the whole story. In some cases, overall headcounts remain steady or may even be increasing. So, how do we reconcile the decreasing trend of ET graduates with concurrent increasing headcount enrollments? The answer may be simple: student customers are shopping for specific skill sets and have become less interested in degree attainment.

While college academic administrators wring their hands over poor retention rates in ET programs, students continue to drop in and out of ET degrees as the workplace dictates. Individual technical courses, short or long-run certificates, and non-credit, skill-specific training events are fast becoming the preference for technology trainees. In other words, even though cumulatively more students are enrolled in ET programs, decreasing percentages of students are degree completers.

Economic Impact of Engineering Technology Education

Ironically, it is the current decline in manufacturing employment—using Ohio as an example—that is one of the key indicators that ET education should increase as the nation steps into its future. In the Executive Summary section of a recent economic prediction report from the Ohio Department of Job and Family Services [20], the following items are called out:

- Some of the decline in manufacturing employment may be attributed to increased labor productivity that enables firms to produce more output with fewer workers. These productivity changes mean that knowledge-based industries are most likely to offer the most employment growth and earnings potential. Postsecondary degree attainment will be the key to success in the coming years.
- Education beyond high school will generally be required for jobs growing faster than average. Employers will continue to need a highly literate workforce with critical thinking and communication-related skills growing in importance.

One of the reasons for the decrease in manufacturing employment is the increasing productivity of the workforce. The application of technology systems to the production environment is making the assembly line of the industrial revolution a by-gone memory. The days of getting out (or dropping out) of high school and jumping into any number of well-paying factory jobs are gone.

Technological improvements have brought about both increased productivity and decreased manpower needs to modern U.S. manufacturing plants. Gone also are the days of thousands of employees working in assembly line operations performing repetitive motions day in and day out. Gone with it are the myriad of employees whose skill sets were basic and focused only on technical process operations. Instead, the day of the technology knowledge worker has arrived. Though fewer, they are in number per facility; greater overall is the need for technologically competent employees.

This is not an isolated phenomenon in Ohio. Nationwide, as the number of individuals being trained in engineering technologies modestly increases, stagnates, or even decreases, the need for highly skilled workers appears to be increasing. In 2004, the U.S. Department of Commerce prepared a report that detailed the results of more than 20 roundtables held with representatives from small, medium, and large companies from a broad range of industries including auto, aerospace, biotech, and semiconductors [21]. Participants of the roundtables were asked to identify the challenges facing their sectors at that time and into the foreseeable future. Feedback was grouped into six categories, four of which dealt with various facets of trade and/or competitiveness and the remaining two were "Reinforcing America's Technological Leadership" and "Ensuring a Highly Skilled and Educated Workforce." Under the latter, the report made clear that advanced labor skills is one of the decisive factors determining our nation's ability to compete in a global economy. The report sounded the alarm that the United States strongly risked undermining its innovation infrastructure if it failed to produce more scientists, engineers, and high-skilled workers.

This sentiment is repeated often in national and state dialogue. In a recent interview, Julian Alssid, founder and executive director of the Workforce Strategy Center in New York City, commented that, as of last year, approximately half of people older than 25 years of age had only a high-school diploma or GED, while more than half of the country's fastest growing occupations required education beyond that level. "In short, it's not that the U.S. doesn't have enough jobs to go around. It's that it doesn't have a workforce trained to fill them" [22].

The two-year college system and, in particular, the ET sector are needed in the emerging global economy to prepare our workforce for the future. Citing the advantage of internships, community involvement, diversity, accessibility, adaptability, breadth of training, and other benefits throughout their book, Gunderson, Jones, and Scanland [23] said, "Community and technical colleges are uniquely positioned to respond to immediate employment needs in their respective communities".

Engineering Technology Legacy Programs

The Council began its investigation due to concern regarding ET legacy program enrollments. The Council was not able to conclusively separate the roles and/or trends of legacy programs from the concerns of overall ET enrollments; yet, some interesting observations were made.

At the same time that enrollment moderately increased over the past several decades, the number of program offerings exploded. An informal survey of participating members at a recent Council meeting revealed that the number of ET program majors has more than doubled since the early 1980s. The Council attempted a more formal analysis of two-year colleges in Ohio from the early 1980s to the present regarding specific program enrollments and found the following. Of the colleges providing data,

- approximately 92 percent reported declines in legacy programs, and
- approximately 64 percent reported increases in new/specialty programs.

It should be noted, however, that this information is far from conclusive and will need to be studied more in depth. Assuming that the data accurately reflects a trend, we conclude that Ohio's two-year system has attempted to be responsive to community needs through development of many emerging and specialized degree paths, sometimes at the detriment of legacy programs.

Conclusions and Recommendations

While we have seen a number of notable trends during the period between the late 1970s and the mid 1980s, we should also look at projections for the future if we plan to make predictions relating to the continued decline in traditional ET programs and the increase in popularity for non-traditional, niche programs such as power technology, electromechanical/mechatronics, and construction [24].

In an effort to identify successful strategies and best practices to answer the concerns raised here and elsewhere, we turn our attention to efforts by other groups around the United States. Potential answers to this and related questions come from a study on high-tech manufacturing's future by the Battelle Memorial Institute [25]. And while the Battelle study focused on the greater Phoenix, Arizona, region, its suggestions are appropriate for all of us. Namely, high-tech manufacturing continues to provide a strong economic employment base and economic diversity to the region; manufacturing wages are higher on average than total private sector wages and wages in the service industry, typically due to increased skill-set requirements for employees [25].

If, then, we assume that high-tech manufacturing will be demanding graduates with ever-expanding skill sets, individual states must develop strategic plans to ensure that they have viable talent pools from which existing high-tech manufacturing can draw, but also use as a draw for new companies seeking regions for building new plants and establishing roots. It is not sufficient to continue business as usual; this can be seen in the decline and demise of traditional or legacy ET programs that have not been willing to adapt. Rather, taking from the recommendations of the Battelle study, we must provide leadership and knowledge not only for the schools offering ET programs but also for the public from which future students will come.

Furthermore, states must forge new outreach programs with industry and local schools to develop or update their pipelines for moving students into ET programs and successfully on to the industrial marketplace. However, beyond business as usual, we must also develop career ladders, talent clusters, and mentoring programs that encourage the development of ET talent. We must also provide, for lifelong learning, opportunities for our dedicated workforce. The reason that there is so much talk about—and studies relating to—the changing skill sets of the high-tech manufacturing employee is because technological advances are occurring at a rate never experienced before. "The key is not just knowledge or skill, but flexible knowledge, flexible skills—those insights and abilities that enable us to learn new material quickly, to move easily from one job to another" [23]. Gunderson, Jones and Scanland also state that "…the most important skill a student can master is learning to learn".

Looking again at the Battelle study [25] and work done by Frenzel and McGlew [26, 27], as well as Brown, Gear, and Kinkley [28], we can summarize the findings from interviews with local industry. The industrial perspective focused on the following three keys areas.

1) Strategic Directions
   - Most companies expect increased sales over the next few years.
   - Engineering requirements are growing more complex, and technicians need more experience in system performance versus component-level knowledge.
   - In light of global competition, a competitive advantage can be gained through products with higher engineering content that are quick to market—thereby reducing labor costs, while increasing quality, product features, and service.
   - According to the Battelle study [25], a key observation was that finding and retaining key employees with appropriate talent and technical skills is becoming a critical challenge. Methods used by a majority of the companies that were surveyed (in the Battelle study) were tuition-reimbursement plans and in-house training, both of which were cited as aiding in student retention.

2) Operational Requirements
   - Battelle [25] and others found that technicians increasingly need more training on a full-systems perspective. Here, the technician would be expected to diagnose and repair a complex system, both of hardware and software, as well as deal with component-level troubleshooting as needed.

3) Workforce Development
   - High-tech manufacturing firms are looking for technicians with broad and well-rounded skill sets—including soft skills—with which employers are able to cross-train their employees.

Based on the data presented in this paper, the Council proposes the following policy changes or organizational commitments from states and individual college administrators.

A) Incorporation of Structured Pathway Programs
   - Create structured career pathways, which have community, industry, government, and education collaboration.
   - Associate's degree ET education should not be seen as an alternative to but rather an inclusion in the successful path of tomorrow's technology employees.
   - Strengthen access to baccalaureate completion programs. Graduates of associate's degree programs are often place-bound and require flexibility in attainment of advanced ET degrees.

B) Consolidation of Emerging and Legacy Engineering Technology Programs
   - Create degrees and certificates with contemporary content and names. Students and industry must be convinced that the investments made in higher education will generate exceptional returns for the future. Majors with cross-functional content and capacity, such as mechatronics and electromechanical engineering technologies, have more appeal to industry and prospective students.

- Funding for emerging technology equipment and training will be key. Investment in capital equipment and professional development related to instruction of emerging technologies must be secured.

C) Focus on Short- to Medium-Length Certificates in a Flexible Format

- Modern industry is calling for highly trained technicians with specific skill sets. These skill sets are sometimes a moving target. Therefore, colleges must be prepared to train both an incumbent and emerging workforce with delivery of courses in less than a full two-year cycle.
- Flexible delivery formats will become necessary to meet the multi-faceted work schedules and busy lives of today's workforce, and online instruction and accelerated course schedules should be incorporated (e.g., one night a week or linked learning).

D) Targeted Marketing and Recruiting for Engineering Technology

- Statewide efforts at marketing advanced technology and manufacturing occupations should become a priority. Public institutions are often reluctant to allocate marketing dollars for programs that have stagnant or moderately increasing enrollments.
- Thomas [29] described one strategic action as "Customer Usage and Satisfaction" and detailed a recommendation to launch a multi-faceted, multi-year statewide marketing campaign aimed at increasing employers' and employees' use of the state's talent development system.
- Thomas [29] also mentions the support of apprenticeships, student internships, faculty externships, and mentoring/coaching initiatives with businesses.

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