Reforming Engineering Technology Education:
Sixth Year Evaluation of the South Carolina Center for Advanced Technological Education

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Academy for Educational Development
Washington, DC

August 2002

Submitted to the South Carolina Center for Advanced Technological Education
South Carolina State Board for Technical and Comprehensive Education
Columbia, South Carolina

Funded by a grant from the National Science Foundation

Acknowledgements

This report would not have been possible without the support of Dianne Brandstadter, Elaine Craft, and Helen Edens of SBTCE who reviewed manuscripts, submitted program information, provided student data at great time and expense, and generally prioritized program evaluation. The evaluators are also grateful for the support of many others: Doug Evans and Mark Braza, AED Senior researchers, for providing technical leadership, conducting sub-studies, writing reports, and preparing presentations to the Center's National Visiting Committee; John Lee and Sue Clery at JBL Associates for managing and analyzing historical student data from the State Board for Technical and Comprehensive Education (SBTCE) database; Bill Kintz and Michele Lugiai of AED for programming Internet-based student and faculty surveys; Susanna Kung and Wen-Tsing Choi, AED graduate fellows, for research, writing, and data base support; Casey Goode, Katherine Branding, and Gustavo Jimenez, AED graduate fellows, for data collection and general research assistance; Antonia Sanin, AED Research Fellow, for completing data collection and analyses under the supervision of David Güemes-Castorena, AED database specialist and researcher, and for writing sections of the report; the National Science Foundation National Visiting Committee members for constructive comments and suggestions; and State Tech college administrators and faculty for hosting evaluator site visits, submitting data, administering student surveys, and otherwise supporting the evaluation.

Abstract

The South Carolina Advanced Technological Education (SC ATE) Center of Excellence undertook in 1996 a six-year, $5 million, NSF-supported systematic reform initiative. Reforms included curriculum and faculty development, and enhanced student services in order to increase the quantity, quality, and diversity of engineering technology graduates throughout the state's 16 technical colleges. The Academy for Educational Development (AED) conducted a six-year evaluation of the Center reform initiative. AED researchers will present a summary of their evaluation.

In spite of the strong demand for engineering technicians, and although the vast majority of engineering technology students entering South Carolina's two-year technical colleges cite "completing an engineering-technology degree" as their main objective, few of these students graduate with engineering technology degrees. For example, after being enrolled in a two-year technical college for four years, only 12% of full-time engineering technology students in the state technical college system in South Carolina graduate with an associate degree in engineering technology.

The SC ATE Center designed, pilot tested, and implemented two new curriculum components: the Technology Gateway, and an Engineering Technology Core. Courses in the SC ATE curricula do not constitute a full-time course load (=12 credit hours), but the courses dominate a student's early course of study. The Technology Gateway is a one-semester, 9 credit hour, pre-engineering technology curriculum targeted to students who are interested in pursuing industrial or engineering technology programs. The

Engineering Technology (ET) Core curriculum is three semesters of coursework, 10 credit hours, 10 credit hours, and 7 credit hours respectively, at the end of which the ATE students matriculate into second-year courses in their specific major to complete an Associate Degree.

The ATE approach differs significantly from the stand-alone, lecture-based courses in the traditional engineering technology program. The five major elements of the ATE approach are:

- integrated courses,
- interdisciplinary teaching teams,
- the use of problem-based learning that model the workplace,
- just-in-time teaching,
- student teaming, supporting a collaborative learning environment, and
- industry scholarships and internships.

Faculty decide to participate in the SC ATE program based on the support of their college, department, and own personal interest. The Center has trained faculty to write curricula and provided them with release time from their teaching duties to do so. At each college, teams of three or four faculty members collaborate to implement the ATE curriculum. SC ATE provides special training or faculty to prepare them for curriculum implementation.

In addition, the SC ATE Center has introduced improvements in communications and marketing as well as ATE scholarships and internships in order to increase the number of students enrolling in ATE courses.

The reform has accomplished the following outcomes:

- The ET Core has steadily increased its enrollment in the past four academic years. In the first year of ET Core implementation, 1998-1999, 25 students enrolled in the ET Core. Three years later (2001-2002), 117 students enrolled in the ET Core, an increase of 368%.
- The ET Core has increased ET graduation rates by over 300 percent.
- By the end of three years, 34.4% of the students have completed the second year of engineering technology courses and graduated, compared to the traditional ET graduation rate average of 10% after three years
- The ET Core provides a sounder foundation for, and increases student success in second-year ET courses.
- The ATE approach develops students' "workplace readiness skills" better than the traditional approach to engineering technology education.
- The SC ATE Program has increased minority enrollments, but minority graduation rates have dropped from historical levels.
- There is no significant difference in ET course pass rates by race or gender.

Students, faculty and employers have expressed satisfaction with the improved program. Students report that they learn more and understand concepts better with teamwork and a problem-based curriculum, Faculty see gains in student performance, depth of understanding, and maturity, and employers say the curriculum is better aligned with their priorities and produces technicians who not only have good technical skills but who also can communicate, work in teams, and solve problems.

The SC ATE approach has been adapted and replicated in South Carolina, and also in Texas, Connecticut, and Kentucky. The Technology Gateway has been adapted and implemented in high school to strengthen technology, mathematics and science preparation of students.

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Acronyms

AED	Academy for Educational Development
ATE	Advanced Technological Education (Program)
ET	Engineering Technology
ILI	Instructional Leadership Institutes
NVC	National Visiting Committee
PBL	Problem-based Learning
SBTCE	State Board for Technical and Comprehensive Education
SC ATE	South Carolina Advanced Technological Education

Introduction

The South Carolina Advanced Technological Education (SC ATE) Center of Excellence Program is a systematic reform initiative of curriculum reform, faculty development, and student services designed to increase the quantity, quality, and diversity of engineering technology graduates throughout the state’s 16 technological colleges. The SC ATE program has been developed, implemented, evaluated, and improved for the last six years.

This report presents the final of a series of external evaluation documents that the Academy for Educational Development (AED) has provided to the National Science Foundation. The following three sections of this report analyze the need for the ATE program (section 1.0), document the implementation of the program (section 2.0), and assess the program’s impact on students (section 3.0), as shown in the next page.

SC ATE Evaluation Report Structure

Problem / Baseline Conditions

Demand for manufacturing technicians in South Carolina is booming (i.e., 29,000 new jobs were created in SC in 1999)

1. There is a shortage of qualified engineering technicians in South Carolina.

2. South Carolina businesses demand employees with "workplace readiness skills". ET graduates lack problem-solving and other workplace readiness skills.

ET students elect when to take required courses in the major, often deferring harder courses to the second year.

Chapter 1

Systemic Reform Interventions

Curriculum Development

Description:
- students are required to take a block of courses presenting core competencies in a prescribed sequence (i.e. core 181- core 182 - core 183)
-based on 6 physical systems (electrical, mechanical, materials, fluids, thermal, and optics)
- integrated blocks of ATE courses (English, mathematics, physics and engineering technology)
- use of active, problem-based learning (PBL), and just-in-time (JIT) instruction
- student teaming on projects
- technology-based learning environment
- 2-yr and 4-yr institution curriculum articulation.
- Technology Gateway (1 semester pre-engineering technology or industrial technology preparation)
-ET Core curriculum (3 semesters of technology-focused general education preparation for all ET majors)

Validity:
- includes workplace research findings
- curriculum's problem scenarios have been critiqued and improved by industry focus groups
- program has been validated by a national peer review group

Section 2.1

Faculty Development

Instructional roles for faculty have been redefined in order to:
- suit multiple intelligences and learning styles of students
- facilitate interdisciplinary faculty teams
- facilitate the adoption of PBL and JIT in the classroom
- foster shared faculty responsibility for a group of students

Training has included participation in Instructional Leadership Institutes, Roundtables, and system wide teleconferences

Section 2.2

Program Improvement

- ATE Scholars and internship program / CSEMS Scholarship grants program

- Strong communications and marketing efforts (quarterly newletter, articles, presentations, videos, resource web site, listservs). SC ATE sponsored marketing plans and marketing materials.

- SC ATE developed a student recruitment forum and published a retention monograph.

Section 2.3

Chapter 2

Student Outcomes

Intermediate Results

- more engaged in studies
- interact with each other more
- hold each other accountable
- take responsibility for own learning
- behave more maturely
- communicate and collaborate better
- become better problem solvers
- interact with faculty more

Long Term Impacts

- More ET graduates:

- More diverse ET graduates

- More skilled ET graduates

Chapter 3

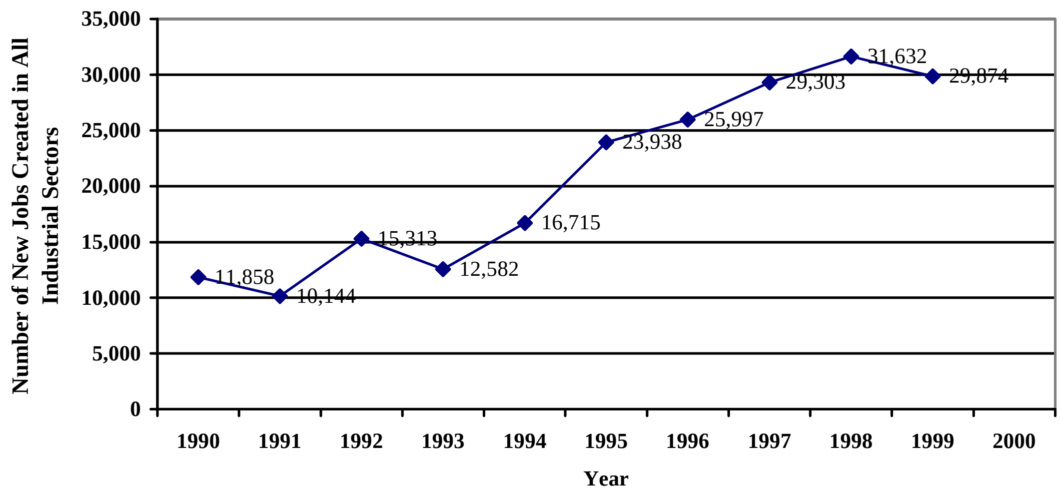
1.0 Problem: There is a Shortage of Qualified Engineering Technicians in South Carolina.

South Carolina faces a shortage of engineering technicians, especially those who are "workplace ready." A recent South Carolina Chamber of Commerce survey found that machine operators were the most difficult positions for employers to fill in 2000, a year in which historically low unemployment made it difficult to fill almost any position (South Carolina Chamber of Commerce 2000). One year earlier, more than 15,000 technology-intensive jobs were unfilled in South Carolina (Persons 1999). The combination of tremendous growth in manufacturing jobs and low output of engineering technology graduates from the State technical college system contributed to the State worker shortage. Employers are not only calling for more workers, but for well-rounded workers who have communication, cooperation, and problem-solving skills in addition to technical skills.

1.1 Demand for manufacturing technicians in South Carolina is booming.

The increasing use of technology among South Carolina manufacturers and influx of new technology-intensive companies to the state are boosting demand for engineering technicians. Throughout the 1990s, South Carolina industry created jobs at a breakneck pace (see Figure 1-1). Manufacturing, the largest and fastest growing sector of the South Carolina economy (Bernat and Repice 2000) created 153,000 manufacturing jobs between 1990 and 1999, accounting for 74% of the total new jobs in the state. In 1999 alone, 1,296 South Carolina manufacturing companies announced capital investments totaling $6 billion and creating 23,039 jobs (South Carolina Department of Commerce 1999). Many of these were major international corporations, including Michelin (1,400 jobs), Siemens Diesel Systems Technology (500), Robert Bosch Corporation Automotive Group (400), BMW Manufacturing Corporation (400), and Mack Truck, Inc. (350). These expansions also generate jobs for other firms that supply parts and services for the larger operations. The U.S. Bureau of Labor Statistics and the South Carolina Employment Security Commission predict that jobs for engineering technicians and related support workers in South Carolina will increase by 20% (3,460) from 1996 to 2006[1]. With such rapid growth, South Carolina manufacturers have a strong demand for engineering technicians.

Figure 1-1. Number of New Jobs Created in South Carolina (South Carolina Department of Commerce 1999), 1990-1999.



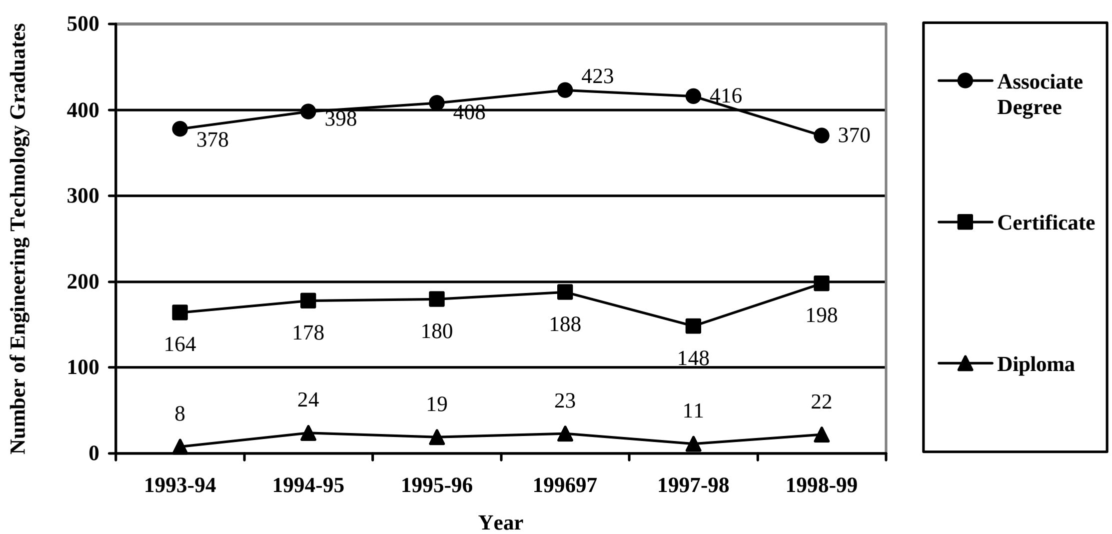
Source: South Carolina Department of Commerce 1999 Annual Report

[1] This figure likely underestimates the total demand for engineering technicians: it is based on employer requests for workers to One-Stop and other placement centers yet many employers do not recruit workers through these means.

1.2 Engineering technology graduates are in short supply.

In spite of the strong demand for engineering technicians, and although the vast majority of entering engineering technology students cite "completing an ET degree" as their main objective (Evans 2000), few South Carolina students graduate with engineering technology degrees. In any given year between 1994 and 1999, roughly 400 students graduated with associate degrees in engineering technology from the state's technical colleges; less than half of that number graduated with certificates, and even fewer completed diplomas (see Figure 1-2). In comparison to the thousands of new manufacturing jobs opening up each year, this output is low. Any of several major manufacturers produced enough jobs in 1999 alone to employ an entire graduating class of ET students.

Figure 1-2. Number of South Carolina Engineering Technology Graduates, 1993 -99.



Source: State Board for Technical and Comprehensive Education Fall 1996, Fall 1998 and Fall 2000. Program Evaluation Reports.

Output is so low because few students, particularly African Americans, complete ET degree requirements and because few women and minorities enroll in engineering technology programs.

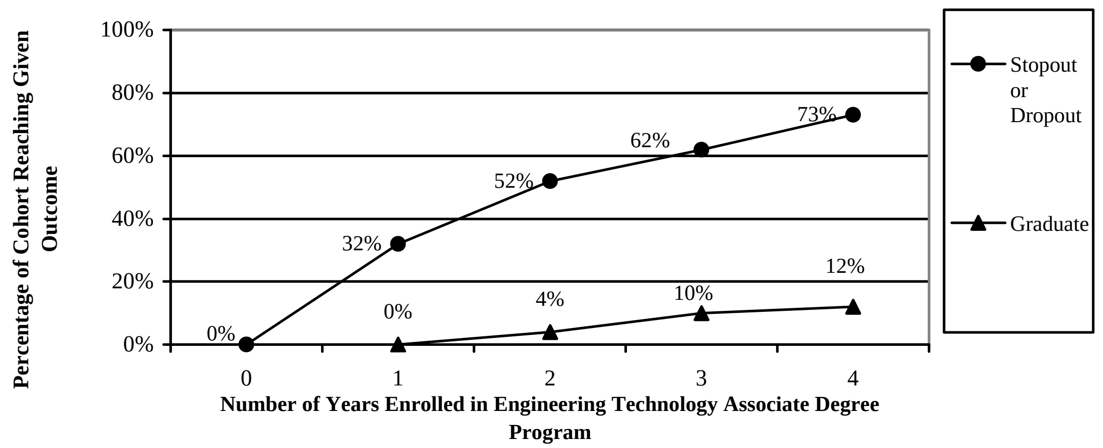
1.2.1 Few students persist through ET programs to graduation.

Only a handful of students who enter engineering technology (ET) programs graduate. After being enrolled in technical college for four years, only 12% of full-time students in the 1992, 1993, and 1994 cohorts graduated with an associate degree in engineering technology[2]; nearly three-quarters (73%) had either stopped out or dropped out after four years[3]. The remainder were either still enrolled but had not completed a degree (18%) or had switched from engineering technology and graduated with an associate degree in a different program (5%), as shown in Figure 1-3.

Of the nine degree program clusters at South Carolina state technical colleges, students in the engineering cluster are among the least likely to graduate. In the 1997-98 academic year, graduates accounted for only 14% of students enrolled in associate degree programs in the engineering technology cluster.[4] Graduation rates in other clusters, by contrast, were as high as 35% (State Board for Technical and Comprehensive Education 2000) (see Figure 1-4). At such low degree completion rates, the State of South Carolina loses most of its investment in engineering technology students. If just one-fourth of all full-time engineering technology associate degree students were to earn a degree, instead

[2] Statistics are based on an Academy for Educational Development analysis of records of engineering technology students from the State System of Technical and Comprehensive Education database.
[3] These students had neither completed a degree nor remained enrolled.
[4] Note that the 12% graduation rate reported above is lower than the 14% rate reported here because the first rate only includes the number of students graduating within four years of study whereas the second rate does not impose a time limit.

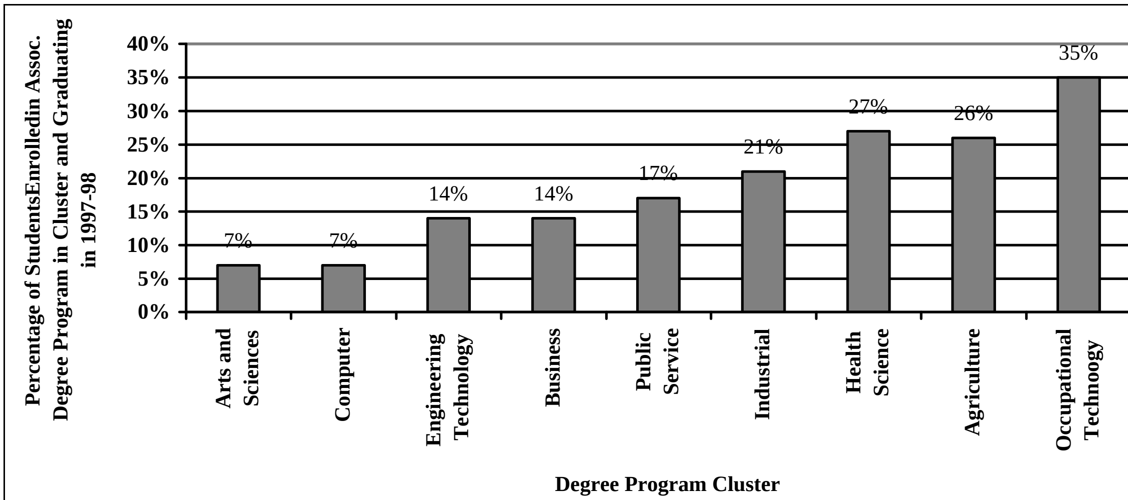
Figure 1-3. Stop out/Dropout and Graduation Rates of Full-Time Engineering Technology Students.



Universe: All students enrolled in (1) associate degree program, (2) the engineering technology cluster, (3) in the 1992, 1993, 0r 1994 cohorts, and (4) full time (N=773).

of the current rate of one-eighth, the state technical college system would double its output of engineering technicians and supply hundreds of badly needed workers to South Carolina industries each year.

Figure 1-4. Cluster Graduates as Percentage of Cluster Enrollment, South Carolina Technical Colleges 1997-98.



Source: State Board for Technical and Comprehensive Education Program Evaluation Report (1998).

1.2.2 African American students are particularly likely to drop out of engineering technology programs.

African American engineering technology students are 50% less likely to graduate than Caucasian engineering technology students. Just 6.5% of blacks beginning ET studies in the 1992, 1993, and 1994 cohorts graduated with an Associate in ET after four years compared to 10% of whites (see Figure 1-5). This disparity is consistent with national trends. A recent U.S. Department of education study found that rates of Asians and whites graduating from undergraduate science and engineering programs were 71% higher than rates for underrepresented minorities (National Center for Education Statistics 2000). If the graduation rate for black students were to rise to parity with the graduation rate for white students, roughly 20 additional students from each annual cohort would graduate.[5] Program improvements that increase graduation rates for all students, in combination with increased recruitment of minority students, would increase this output even more.

The ethnic achievement gap begins even before students enroll in college. African American students in South Carolina are less academically prepared for college, on average, than their Caucasian peers. They score significantly lower in all subject areas of the Scholastic Aptitude Test (SAT), the American College Test (ACT), and the state High School Exit Examination and they are far less likely to complete 20 or more high

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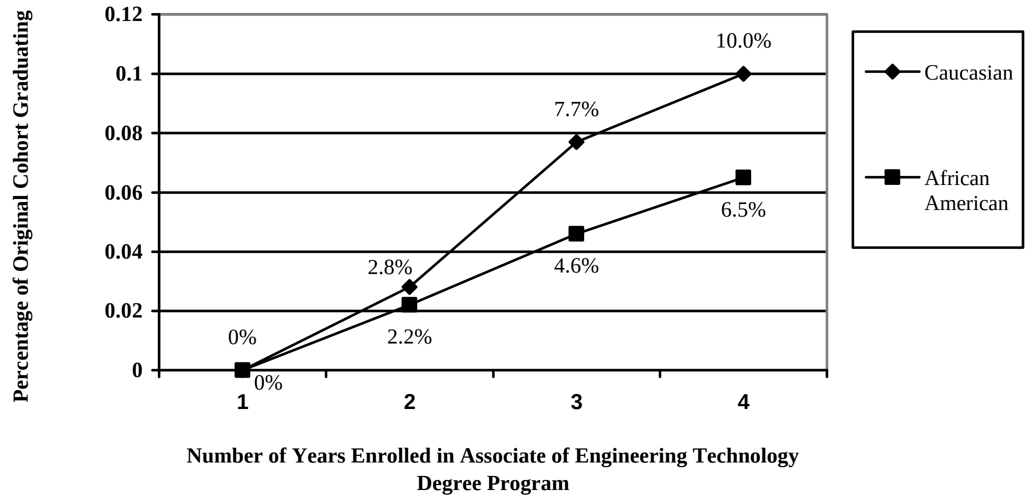
[5] In the 1995-96 academic year, for example, there were 3,153 students enrolled in associate degree programs in the engineering technology cluster, according to the Technical Education System Program Evaluation Report for that year. Approximately 19% of these students were black, according to AED analysis of the state system database. If these 599 students persisted and completed according to historical rates, 39 would graduate within four years. If this rate were brought into parity with graduation rates of white students (10%), an additional 21 students would graduate.

Figure 1-5. Engineering Technology Associate Degree Students Graduating Rates by Race and Number of Years Enrolled.



Source: AED Analysis of State Board for Technical and Comprehensive Education database. Universe: All students enrolled in (1) associate degree program, (2) the engineering technology cluster, and (3) in the 1992, 1993, or 1994 cohorts (N=1707).

school academic courses, the minimum number recommended by the College Board.[6] In spite of this gap, the State Tech system historically has not had a special program to prepare under-achieving students for engineering technology.

A second cause of the ethnic graduation disparity may be a disproportionate level of financial need. National research indicates that a lack of financial support is a major reason that so many underrepresented minorities drop out of post-secondary science and engineering programs (National Center for Education Statistics 2000). South Carolina research corroborates this, indicating that minority engineering technology students are more likely than their Caucasian peers to require financial aid to finish their degrees

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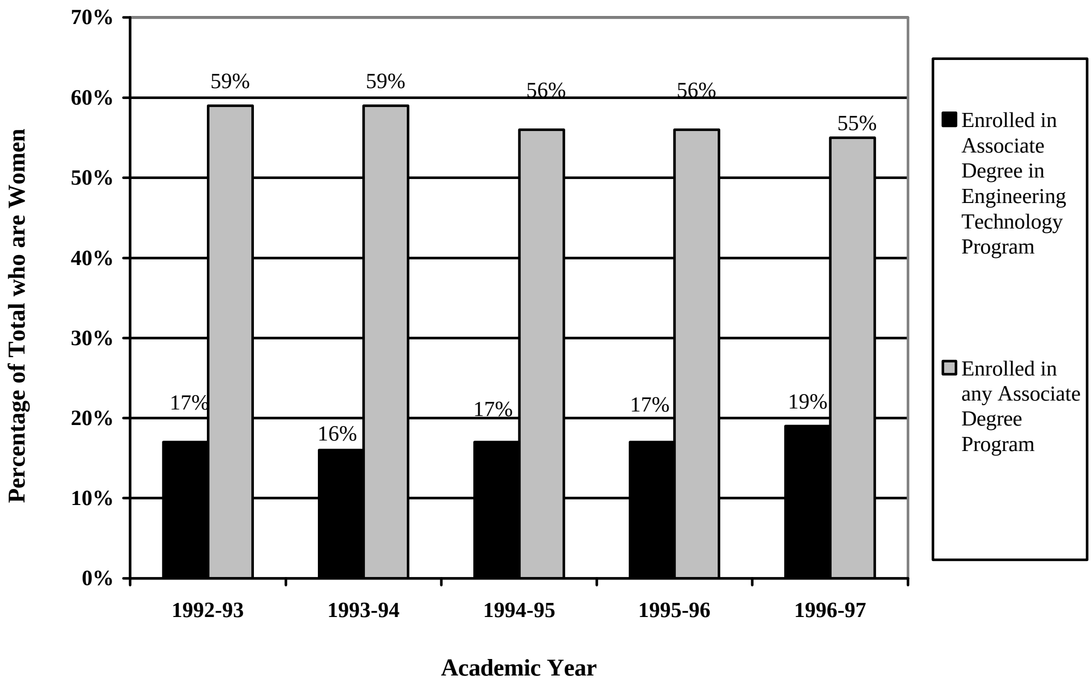
[6] These gaps are correlated with levels of parental education and levels of school resources. Nearly twice as many black as white South Carolina students have parents whose highest level of education is a high school diploma, according to the "1999 South Carolina SAT Report" available at www.state.sc.us/sde/reports. Ninety-five percent of South Carolina public school teachers indicated in a recent survey that education resources were not distributed fairly across public schools, according to "What our Children Need: South Carolinians Look at Public Education," a 1997 Report from Public Agenda prepared for the South Carolina Department of Education.

(Evans 2000). On average, African Americans in South Carolina have much less ability to pay for college. The per capita income for black South Carolinians ($6,800) was less than half that for white South Carolinians ($14,115) in 1989, according to the 1990 US Census (South Carolina Budget &Control Board Office of Research and Statistics 2002). In spite of this financial need and graduation disparity, no scholarships specifically directed at engineering technology students have been historically available in the South Carolina technical college system.

1.2.3 Few women and minorities study engineering technology.

Few women enroll in engineering technology programs in South Carolina. From fall semester 1992 to spring semester 1998, less than one in five engineering technology students in the South Carolina technical college system was female even though women comprised over half of total college enrollments. Although there was a small spike in female enrollment in the 1996-97 school year, female enrollment remained roughly constant during the mid-1990s, ranging between 16% and 19%. Meanwhile, the proportion of women enrolled in all associate degree programs was roughly three times higher, ranging between 55% and 59% during the same years (see Figure 1-6). This gender gap mirrors national trends. In the late 1990s, women made up only 13% of all engineering students in associate degree programs (National Center for Education Statistics 2000) and 19% of those in bachelor degree programs (National Science Foundation 2000). If the number of female engineering technology students were to rise by half, so that the proportion of women in ET programs increased from 18% to 27%, and if historical persistence and graduation rates were to remain constant, roughly 30 additional students would graduate from each annual cohort.[7] With additional efforts to boost overall graduation rates, this number would be even higher.

Figure 1-6. Percentage of Female Associate Degree Engineering Technology Students.



Source: AED analysis of State Board for Technical and Comprehensive Education database

Low female enrollment in engineering technology programs may be caused, in part, by a lack of women who are adequately prepared in science and mathematics. National studies indicate that although girls take a similar number of most high school mathematics and science courses as boys, they achieve a lower level of proficiency in

[7] In the 1995-96 academic year, for example, there were 3,153 students enrolled in associate degree programs in the engineering technology cluster, according to the Technical Education System Program Evaluation Report for that year. Approximately 19% of these students were women, according to AED analysis of the state system database. If female enrollment were to increase by 50%, from 18% to 27%, an additional 284 students would enroll in ET programs, assuming male enrollment remained constant. If these 284 students persisted and completed according to historical rates for females, 28 would graduate within four years.

advanced courses (Hanson and NCES 1996). Although South Carolina women score higher than men on the verbal sections of the American College Test (ACT) and the South Carolina High School Exit Examination, they score lower on the mathematics and science sections. They also score lower than men on both the verbal and mathematics sections of the Scholastic Aptitude Test (SAT). Once enrolled in engineering technology programs, however, women are more likely than men to graduate. Ten percent (10%) of women beginning ET studies in the 1992, 1993, and 1994 cohorts graduated with an Associate in ET after four years compared to just eight percent (8%) of men. This is consistent with national trends.[8] A National Science Foundation study, for example, shows that more women (5.4%) than men (4.8%) completed an associate degree program within five years (National Science Foundation 2000).

Minorities, particularly African Americans, are also underrepresented in engineering technology programs. Roughly the same percentage of minority students (19%) enroll in associate degree programs in engineering technology as enroll in associate degree programs overall. Relative to students enrolled in all South Carolina technical colleges for any purpose (including those pursuing diplomas, certificates, and/or simply further education in addition to those pursuing degrees), however, enrollments of minority students in engineering technology programs are low. Of the 54,100 students enrolled in credit programs in the South Carolina technical college system in fall 1996, 28% (15,000) were black (South Carolina Technical Education System 1997). By comparison, in that same year, only 20% of engineering technology degree students were

[8] These figures are based on an AED analysis of State Tech data. See footnote 2.

black. The disparity in academic preparation and financial resources mentioned in section 1.2.2 likely explain this disparity.

1.3 South Carolina businesses demand employees with "workplace readiness" skills, although traditional engineering technology programs do not emphasize these skills.

Surveys of South Carolina employers indicate that "workplace-readiness skills," in addition to technical skills, are critical for engineering technicians, yet these skills are rarely taught in the traditional program of stand-alone, lecture-based courses. A 2000 survey by the South Carolina Chamber of Commerce of over 400 businesses found that employers are most interested in workers who can cooperate, communicate, solve problems, and act responsibly (see Table 1-1). Even for machine operators, the top five skills – integrity/honesty, knowing how to learn, responsibility, team player, listening, and self esteem – were non-technical. State technical college faculty members visited 18 South Carolina manufacturers and found that employers seek engineering technicians who can think, communicate, and collaborate with others to get jobs done. For example, not only

Table 1-1: Top 15 Worker Skills in Demand by South Carolina Employers.

Rank	Skill
1	Integrity and Honesty
2	Team Player
3	Listening Skills
4	Responsibility
5	Knowing How to Learn
6	Self-esteem
7	Reading Skills
8	Social Skills
9	Reasoning Skills
10	Ability to Allocate Time
11	Interpret and Communicate Information
12	Self-Management Skills
13	Problem-Solving
14	Working with Diversity
15	Arithmetic Skills

Source: South Carolina Chamber of Commerce "Skills that Work 2000: A Comprehensive Analysis of South Carolina's Workforce, Critical Jobs, and Necessary Skills."

must a worker be able to analyze graphs, he or she must be able to produce these graphs on a computer and explain their significance to others (Mack 1998).

The traditional engineering technology curriculum, however, is not structured to prepare students to integrate mathematics, physics, and engineering technology and communication and interpersonal skills to solve the complex, open-ended problems they are likely to encounter in a high-tech manufacturing workplace. Teamwork and problem-solving are skills rarely taught in textbook and lecture-based courses, where students apply their skills to textbook exercises. Employers, administrators, and faculty indicated the importance of teaching workplace readiness skills in engineering technology programs during site visits by AED evaluators. One faculty member expressed his opinion by saying that “the answer is not always on page 49. The traditional model does not prepare you to solve a problem.”

2.0 Systemic Reform Interventions of the SC ATE Program

The SC ATE approach to engineering technology education, developed by the South Carolina Advanced Technological Education (SC ATE) Center of Excellence and funded by two three-year grants from the National Science Foundation's Advanced Technological Education program, was intended to increase the quantity, quality, and diversity of engineering technology graduates by tailoring classroom teaching to workplace reality.

The ATE approach consists of three program components: (1) curriculum development, (2) faculty development, and (3) program improvement.

2.1 Curriculum development

2.1.1 Technology Gateway and ET Core curriculum

The SC ATE Center designed, pilot tested, and refined the Technology Gateway and the Engineering Technology Core Curriculum. The Technology Gateway is a one-semester pre-engineering technology curriculum targeted to students who are interested in pursuing industrial or engineering technology programs (e.g. electronics, engineering graphics, mechanical, civil, chemical, and general engineering technology). Technology Gateway students take an engineering technology, a mathematics, and an English course. The Technology Gateway has been accepted as dual credit (high school and technical college credit). The Engineering Technology (ET) Core curriculum is composed of three semesters, at the end of which the ATE students matriculate into courses in their specific major to complete an Associate Degree. ET Core students take engineering technology, physics, mathematics, and English courses in each of three semesters, except for the third semester which excludes English because degree requirements have been met. Even though the curriculum was initially designed for two-year technical colleges, the SC ATE Center of Excellence has worked to stimulate articulation agreements between South Carolina technical colleges and SC State University that would create pathways for ET graduates to continue their studies at four-year institutions and earn Bachelor degree of Science in Engineering Technology (see Figure 2-1).

Figure 2-1. Engineering Technology Educational Pathways.

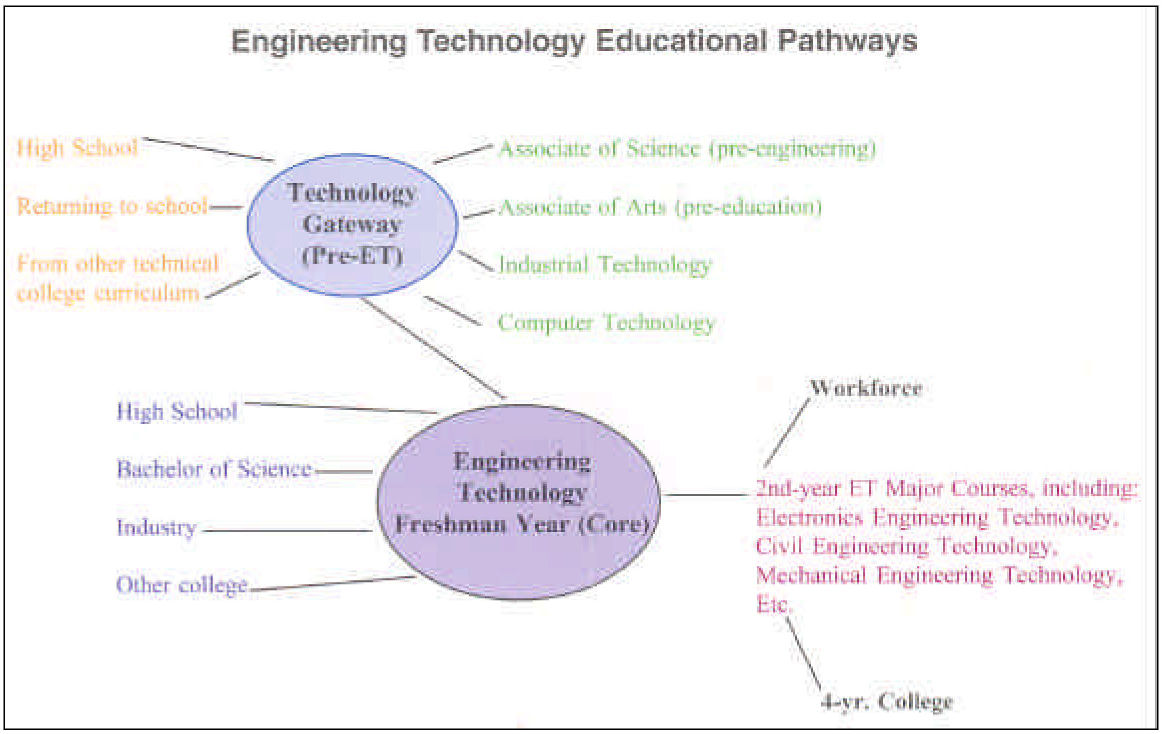


Table 2-1 presents the distribution of student projects by semester. Each project consists of a workplace scenario that poses a “real world” problem to solve. As can be seen, the curriculum is built around physics, because physics offered a finite number of systems that paralleled the ET majors and numerous industrial applications.

Table 2-1. Curriculum projects of the Technology Gateway and the ET Core

Technology Gateway Six (6) projects	**ET Core** Sixteen (16) projects		
? Introduction to Technology Careers ? Simple Machines ? Basic Electricity ? Optics ? Temperature Measuring Devices ? Hydraulic Jack	? **First Term (6)** **Electrical** 1. Resistance 2. Current 3. Voltage 4. Capacitance 5. Motors **Thermal** 6. Thermal	? **Second Term (6)** **Mechanical** 1. Displacement / Velocity 2. Forces 3. Energy 4. Equilibrium 5. Rotation **Fluids** 6. Fluids	? **Third Term (4)** **Optics** 1. Projection 2. Micro-measurement **Materials** 3. Properties of Materials 4. Deforming Materials

One of the purposes of implementing SC ATE was to increase retention rates. Achieving high retention rates on the first year of any engineering program is critical, since typically these are the students that drop out. The key lies in getting more students through 100-level general education courses. Of the students who stop out or drop out of engineering technology, nearly half (44%) do so within the first year when students typically take 100-level courses. This is equivalent to a 56% completion rate within the first year. AED reviewed student records from two South Carolina technical colleges and discovered that only 35% of engineering technology students in the 1995 and 1996 cohorts had advanced to 200-level ET courses by fall 2000.[9]

Interviews and focus groups with South Carolina technical college students, faculty, and administrators indicate that general education courses, which include English, mathematics, and science, pose the biggest stumbling block to student

[9] Two colleges offering the ATE program during the 1999-2000 academic year submitted selected information for students who began their engineering technology studies in either 1995 or 1996 at their college. Of the 240 students, only 84 had persisted to 200-level ET courses by the fall of 1999.

persistence and graduation.[10] Many engineering technology students do not see the relevance of these theoretical courses or find the abstract subject matter too difficult and subsequently abandon their pursuit of an ET degree. The five major elements included in the Technology Gateway as well as in the ET Core (section 2.1.2) are designed to provide students with sufficient motivation to persist, while enhancing their academic success and developing their workplace skills.

2.1.2 Description of the ATE approach

With the exception of laboratories, the ATE approach differs significantly from the stand-alone, lecture-based courses in the traditional engineering technology program. The five major elements of ATE approach are the integration of courses, and the use of problem-based learning, just-in-time teaching, student teaming, and industry scholarships and internships.

2.1.2.1 Integrated courses

Course integration, according to education research, makes abstract concepts more comprehensible and more relevant to ET students. Therefore, the ATE approach integrates these subjects with each other and with engineering into a block of three or four courses taught by a team of instructors. As a result of the integrated SC ATE curriculum, students acquire all prerequisite skills for entering the second year of ET study. As one ATE faculty member put it, “The integration is the innovation.”

[10] AED researchers conducted telephone interviews with 20 ATE teaching faculty in November 1999 and conducted on-site interviews with students, faculty and administrators at seven ATE implementation colleges in October 2000.

2.1.2.2 Problem-based learning

Being able to apply certain concepts to solve real-life problems, according to ATE workplace research and the tenets of PBL, is more important than being able to recall every concept in a disciplinary canon. The ATE curriculum is structured around a series of workplace problems – based on extensive faculty research in South Carolina industry – that students work on. The Problem-Based Learning (PBL) process includes defining the problem, determining what existing knowledge may be used to address the problem as well as what additional knowledge must be obtained, the self-directed effort of gathering information and sharing it with the group, generating solutions and presenting them to classmates and teachers, and performing self- assessments as well as peer-assessments. Faculty act as coaches or facilitators, monitoring the progress of student solutions, answering questions, and teaching concepts as necessary. In addition to traditional testing methods, faculty collaborate in developing scoring rubrics for use with alternative student assessment methods.

The learning environment that surrounds PBL simulates the high performance workplace environment. The problem-based approach to learning teaches students how to apply their skills and to learn on their own, which helps them mature more quickly and become more independent. Students may not necessarily perform better on a standardized test but they are much better at demonstrating their knowledge by building a circuit, for example. Box 2-1 provides the objectives that the Southern Illinois University believes PBL accomplishes.

Box 2-1. Problem Based Learning produces learners who…

- Engage the problems they face in life and career with initiative and enthusiasm.
- Problem-solve effectively using an integrated, flexible and usable knowledge base.
- Employ effective self-directed learning skills to continue learning as a lifetime habit.
- Continuously monitor and assess the adequacy of their knowledge, problem-solving and self-directed learning skills.
- Collaborate effectively as a member of a group. [11]

2.1.2.3 Just-in-time

In order to teach disciplinary concepts within a problem-based curriculum, the ATE approach incorporates "just-in-time" instruction. Traditionally, instructors introduce concepts so that each one builds upon the previous one according to the logical sequence within an academic discipline. With the ATE approach, faculty introduces academic concepts exactly when students need them to solve a workplace scenario. An English instructor, for example, might teach students to draft official memos so students can better present their problem scenario solutions to a hypothetical supervisor. Likewise, a mathematics instructor might explain geometric concepts as students determine the appropriate length of a conveyor belt for a workshop of given dimensions.

2.1.2.4 Student teaming

In the ATE approach, students work in teams to complete all major classroom projects. They depend upon each other to complete assignments. According to education research, by working together, students engage in their coursework, assist each other with difficult concepts, and develop the critical workplace skills of cooperation, communication, and responsibility. In order to facilitate student teaming, faculty employ techniques from multiple intelligences, learning styles, and cooperative learning.

Table 2-2. Student teams at Spartanburg Technical College.

2.1.2.5 Industry scholarships and internships

Traditionally, no scholarships have been available exclusively for engineering technology students in the South Carolina technical colleges. As mentioned in Section 1.0, many students, particularly minorities, drop out of engineering programs in technical college because they do not have enough money to stay in school. Scholarships and internships allow students to continue to work towards their degree while earning income and gaining relevant work experience. The ATE Center encourages colleges to solicit scholarships and internships for ATE students through local business consortia. Section 2.3.2 further describes the scholarships and internships available to ATE students.

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[11] Retrieved June 24, 2002, from Southern Illinois University Web site: //www.pbli.org/pbl/pbl4.htm

Table 2-3 summarizes the differences between the Traditional method and the ATE approach.

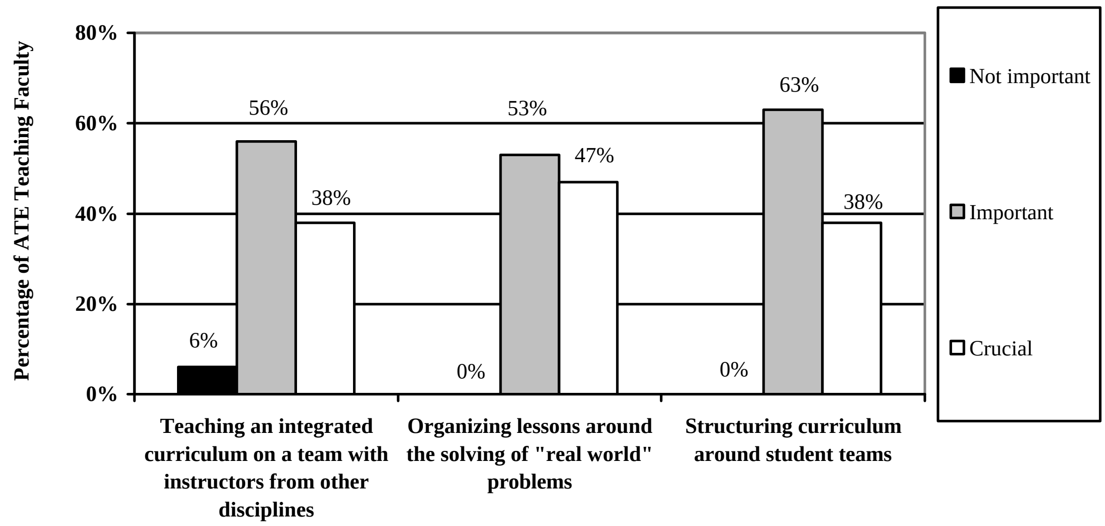
Table 2-3. Comparison between Traditional and ATE Approaches to Engineering Technology Education.

	Traditional Approach	ATE Approach
Relationship among General Education Courses	Separate	Integrated
Focus of Curriculum	Learning Academic Concepts	Solving Workplace Problems
Sequence of Academic Concepts	Logic of Academic Discipline	Just-in-Time
Students Interaction and Assessment	Individual Work	Individual Work and Teamwork
Financial or Employment Support	No scholarships or internships specifically for ET students	Full scholarships plus part-time internships specifically for ET students
Course Scheduling	50-minute class periods	Blocks of class periods to accommodate three and four-hour teamwork

2.1.3 Incorporation of the elements of the ATE approach

Integrated courses, problem-based learning, just-in-time, and team-working are all implemented simultaneously under the ATE approach. Student teams remain in their workspace discussing the problem they have been assigned, while interdisciplinary instructors come and go to coach and deliver "just-in-time" instruction. Box 2-2 describes how the ATE approach works in a classroom. Figure 2-2 indicates the importance that ATE faculty assign to three of these aspects: team teaching, problem-solving, and student-teaming.

Figure 2-2. Faculty Survey – The importance of different ATE approaches.



Source: Fall 2000 ATE Faculty Survey (N=32).

Box 2-2. Implementing the ATE approach in a classroom setting

Walking into an ATE classroom, an observer immediately notices something different: instead of listening to a lecture and taking notes, students work on solving industry-based problems.[12] During the second unit of the Technology Gateway, which AED evaluators observed at several colleges, student teams figure out a way to move heavy aluminum coils to a warehouse loading dock using only simple tools and muscle power. At the beginning of the unit, students experiment with the properties of simple machines. Four students attach metal washers to the end of a lever to test the amount of force required to raise a small weight. They repeat this test several times, each time varying the number of washers, and record the outcomes into a spreadsheet. Other groups of students conduct similar tests with inclined planes and pulleys. The physics instructor visits each group to answer questions and to lead discussions. When the bell rings, it is the faculty – not the students – who switch classrooms. The mathematics instructor shows students how to enter data from their experiments into spreadsheets, how to graph scatter plots, and how to estimate the relationship between weight and force. After several days, students apply these concepts to design scale models of simple machines, their solutions to the problem scenario. One team builds a pulley powered by a hand crank; another presents a working conveyor belt. Now, the communications instructor helps students communicate their solutions by showing them how to summarize information, explaining principles for designing PowerPoint slides, and demonstrating public speaking techniques. To complete the unit, each team describes its model in a formal presentation to the rest of the class.

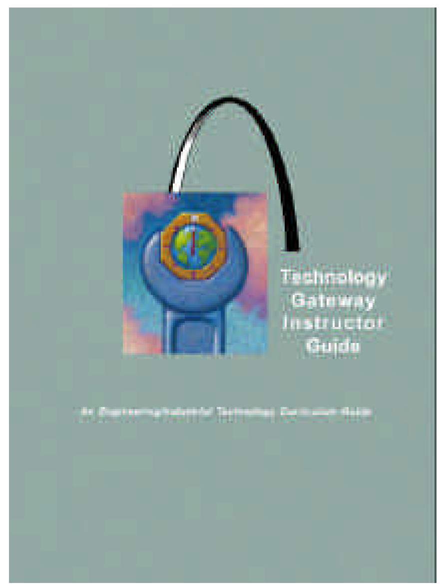
[12] This description is based on AED evaluators November 2000 site visits and review of curriculum materials.

2.2 Faculty Development

Faculty decide to participate in the SC ATE program based on the support of their department and their own personal interest. Full-time and adjunct SC ATE faculty for the 2001-2002 academic year was composed of 135 teachers, of which 59 were female, and 12 were African-American.

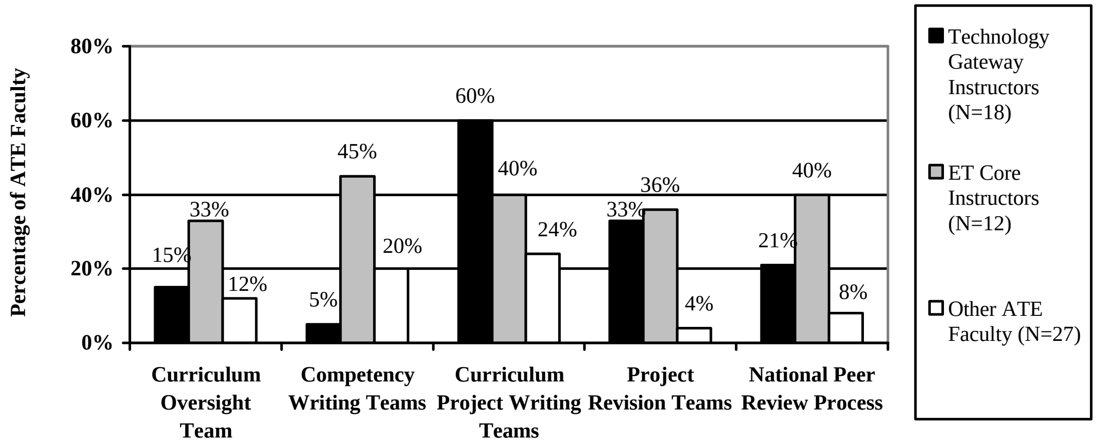
2.2.1 Curriculum development

The Center has trained faculty to write curricula and provided them with release time from their teaching duties to do so. The curriculum-writing process began with Curriculum Oversight Teams that identified the major components of the curricula such as ATE course descriptions. Then, Competency Writing Teams drafted lists of the learning outcomes students should achieve in ATE courses. The Curriculum Project Writing Teams, which included 30 faculty members, visited over 60 manufacturing sites to develop real-life problem scenarios. Project Revision Teams, which included one representative from each discipline, made subsequent revisions to the curriculum and Campus Teaching Teams pilot-tested the curriculum. Figure 2-3 presents the various faculty member roles in curriculum development.



The curriculum was reviewed and validated in industry focus groups and by national peer reviewers.

Figure 2-3. Faculty Survey - Curriculum Development Participation[13]



Source: Fall 2000 ATE Faculty Survey.

2.2.2 Learning how to implement the ATE curriculum

2.2.2.1 Curriculum-implementation training

At each college, three or four faculty members implement the ATE curriculum as a team. The SC ATE Center recommends that all faculty who will teach the ATE curriculum take the teaching-team training. These training sessions last one to three days — depending upon how much training a faculty member needs — and cover problem-based learning, team teaching, learning styles, instructional technology, student assessment, and other pedagogical concepts. Supplementing these sessions are the annual Instructional Leadership Institutes (ILI) where faculty are provided with an in-depth study of some concept or strategy such as cooperative learning and given an opportunity to discuss implementation of the ATE curriculum and build upon concepts

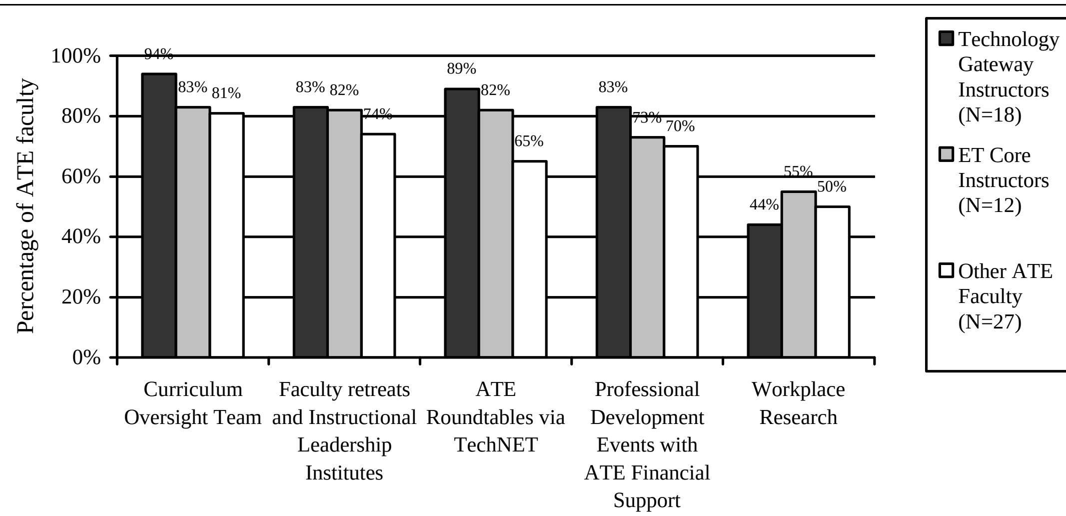
[13] Note that rates of involvement of other ATE faculty are likely overestimates. While 94% of teaching faculty responded to the faculty survey, roughly one fourth of non-teaching faculty members did. Those that did respond likely were probably the ones who were more likely to have participated in curriculum-writing events.

introduced in the training sessions. ATE faculty training events also include technology workshops and ATE Roundtables via the state teleconference system. Finally, ATE funded several faculty members to attend national conferences on technical education. Table 2-4 presents the kinds of faculty training activities undertaken, and Figure 2-4 presents the relative percentages of ATE teaching faculty participating in each.

Table 2-4. Faculty training activities.

	1999-2000	2000-2001	2001-2001
Campus-based demonstration projects	N/A	9	3
ATE Roundtables (# faculty)	50 (from 11 colleges)	65 (from 10 colleges)	82 (from 13 colleges)
Teaching Team Training	N/A	38	57
Workplace research hours	N/A	60 (from 1 college)	220 (from 13 colleges)

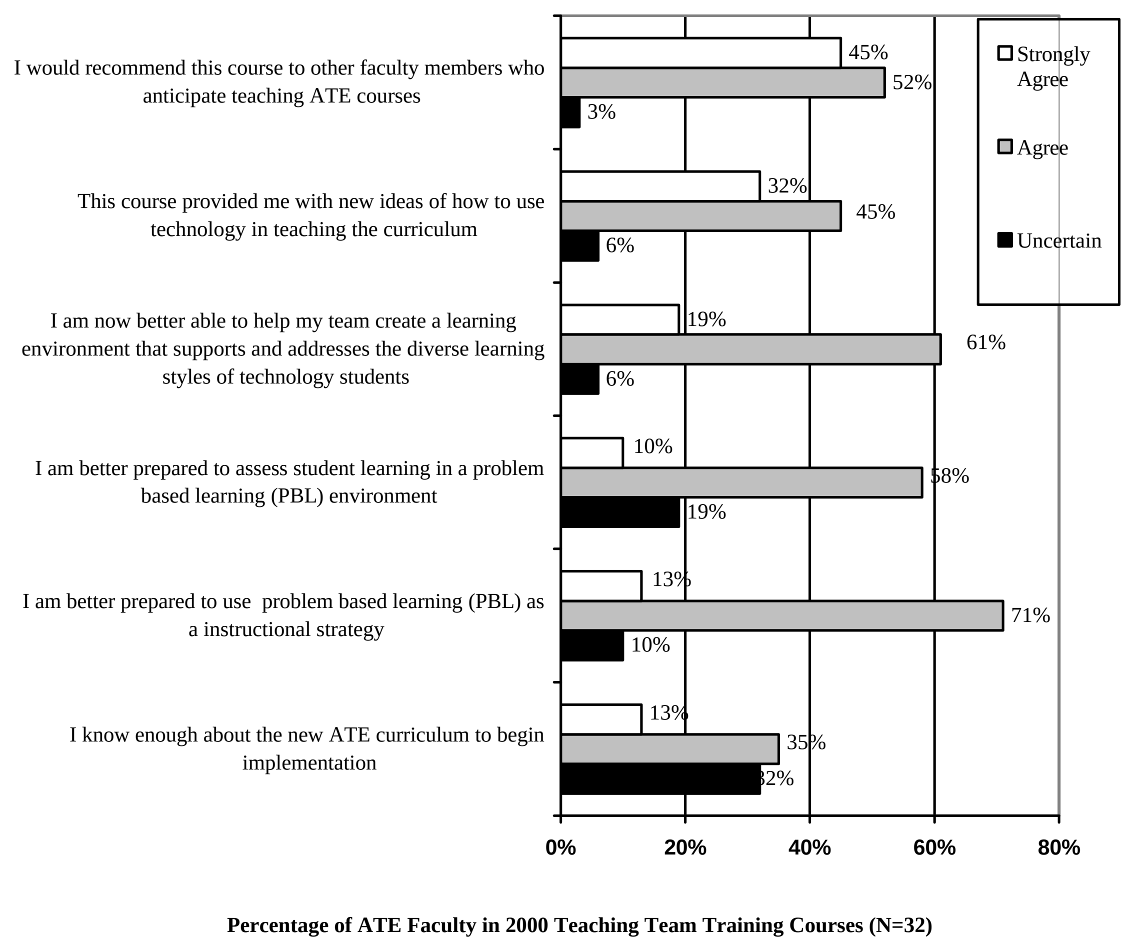
Figure 2-4. Faculty Survey - Faculty Training and Development.



Source: Fall 2000 ATE Faculty Survey

Each teaching faculty member interviewed indicated that the ATE faculty development opportunities improved his or her teaching ability. In particular, they indicated that ATE training allowed them to observe different colleges across the state, develop a supportive network of peers, learn new pedagogical theories, visit workplaces to learn what industry expects of workers, and use technology in the classroom. Faculty were less confident, however, about whether they knew enough to implement the ATE curriculum in the classroom (see Figure 2-5).

Figure 2-5. Faculty Survey – "As a result of this course…"

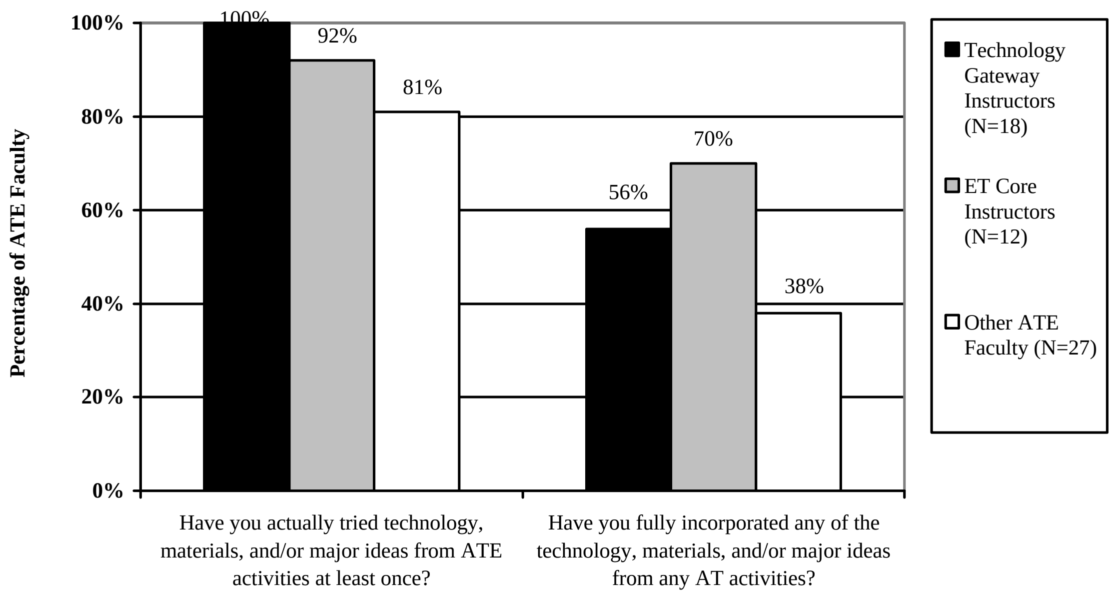


Source: Spring 2000 SC ATE Faculty Survey

2.2.2.2 Faculty apply the ATE approach to their ET Core classes, and to a lesser extent, to their Technology Gateway classes.

ET Core faculty implement the ATE approach more fully than do Technology Gateway faculty. Two-thirds of ET Core faculty members indicate that they have "fully incorporated any of the technology, materials, and/or major ideas from any ATE activities" compared to 56% of Technology Gateway faculty (see Figure 2-6.)

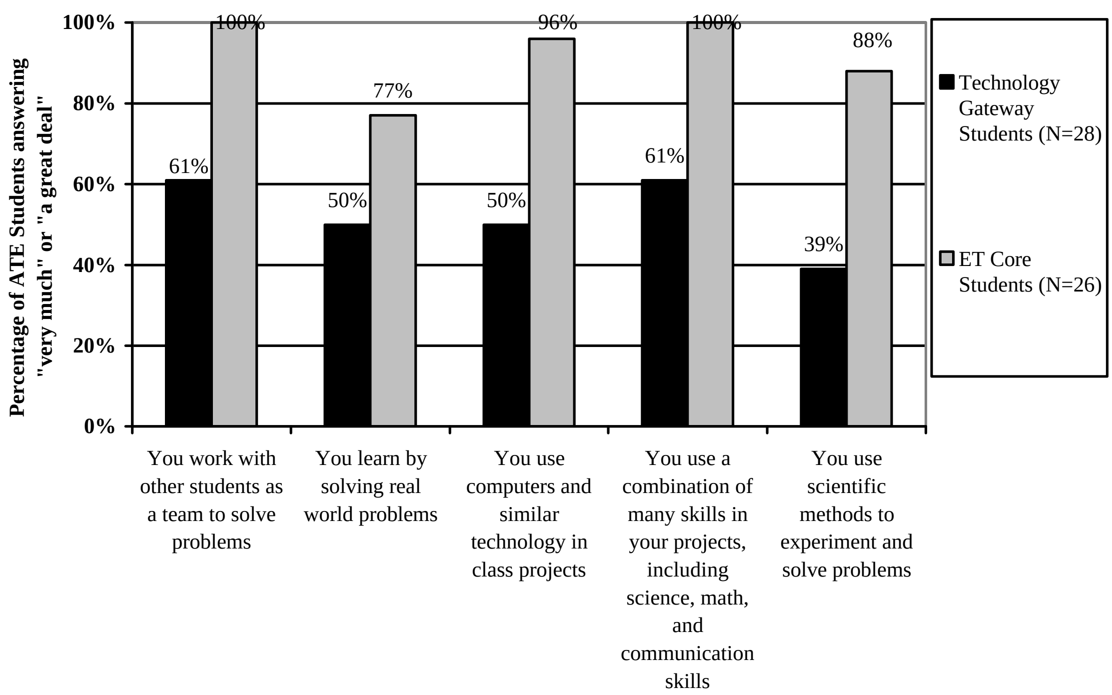
Figure 2-6. Faculty Survey - Faculty Applies the ATE approach to their classes.



Source: Fall 2000 ATE Faculty Survey.

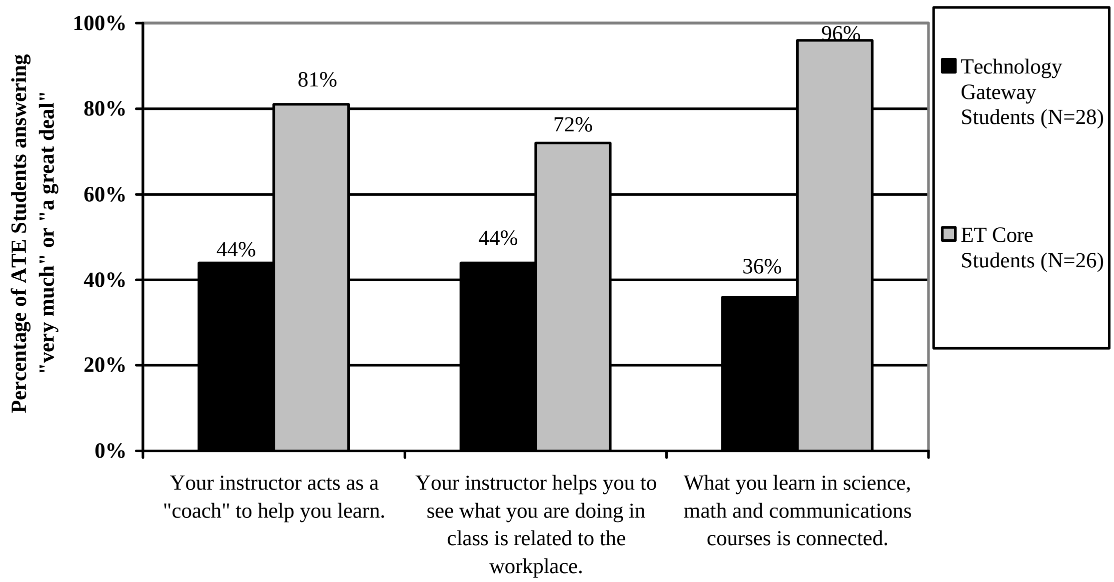
From the students' perspective, however, this difference is more dramatic. Perhaps because the Technology Gateway is primarily driven to increase the mathematics ability in students, ET Core students were far more likely than Technology Gateway students to say they use scientific methods to experiment and solve problems, use a combination of skills in class projects, use computers to solve problems, learn by solving real world problems, and work with other students as a team (see Figure 2-7.) ET Core students were also more likely to indicate that their instructors act as a coach, that their instructors help them to see the relationship between class work and the "real world," and that general education concepts are connected. The largest disparity in the responses of these two groups was that nearly all ET Core students (from the three semesters) indicated that what they learn in science, mathematics and communications "is connected" while just over one-third of the students from the one-semester Technology Gateway indicated the same (see Figure 2-8).

Figure 2-7. Student Survey – Methods Used in ATE Courses (1).



Source: Fall 2000 End-of-Semester ATE Student Surveys.

Figure 2-8. Student Survey – Methods Used in ATE Courses (2).



Source: Fall 2000 End-of-Semester ATE Student Surveys.

There are several plausible explanations for the disparity in ATE implementation between ET Core and Technology Gateway classrooms. First, the two groups of students are at different educational levels and may have different perceptions of course activities. Since ET Core students are more advanced academically, and spend three semesters in the ET Core versus only one semester in the Technology Gateway, they may be more likely to see the connections between the general education subjects. Second, the content of the ET Core is more sophisticated and may better lend itself to applying academic concepts to workplace situations. For example, since students in the Technology Gateway are just beginning to use college-level skills, it might be more difficult to engage them in using the scientific method. Third, as mentioned in Section 3, many faculty members believe Technology Gateway students are less mature than other students. It could be that this level of maturity makes it more difficult to implement active learning concepts. At the same time, many concepts – such as faculty "coaching students" and students working together in a team – are effective regardless of the level of students and yet are being used less in Technology Gateway classrooms.[14] Fourth, there are no discernable differences in the level of participation in ATE faculty development or curriculum writing events that could explain the difference in implementation.

2.2.2.3 ATE faculty apply some ATE methods to their non-ATE courses.

ATE faculty members apply ATE teaching methods to their non-ATE courses. One hundred percent of ATE teaching faculty members and 91% of other ATE faculty members surveyed (that is, faculty who were not currently teaching the Technology Gateway or ET Core) indicated that they apply at least one of the following methods – multiple intelligence theory, student learning styles, workplace research findings, teamwork skills, and active learning – to their non-ATE courses (see Figure 2-9).

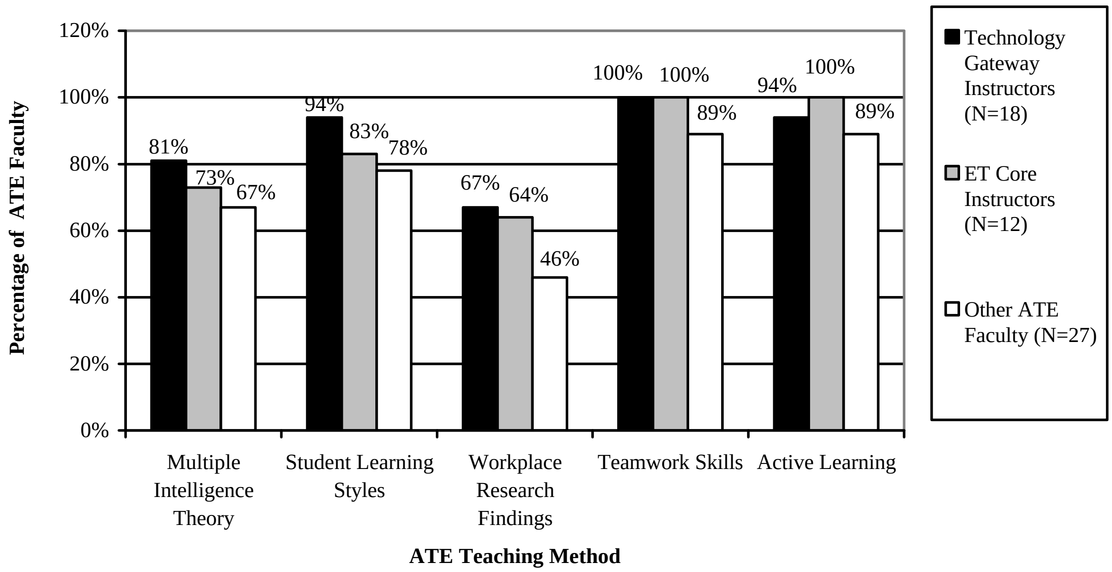
During site visits and telephone interviews, faculty said they now lecture less and lead more student-centered activities – such as computer-based projects, weekly journal entries, and exercises based on customized hand-outs rather than textbooks. Other faculty said they incorporate the concepts of multiple intelligence and learning styles into non-ATE courses.

Some instructors mentioned that the lack of problem-based, integrated curricula in non-ATE courses prevented them from fully implementing ATE methods in those courses. Using the just-in-time instructional method, for example, is difficult to apply to

[14] It is possible that some of this difference is random fluctuation caused by uneven response rates to end-of-semester student surveys.

a curriculum that is structured around academic concepts rather than workplace problems. Others, however, mentioned that they overcome this obstacle by using textbooks less and

Figure 2-9. Faculty Survey – Methods Used in ATE Courses.



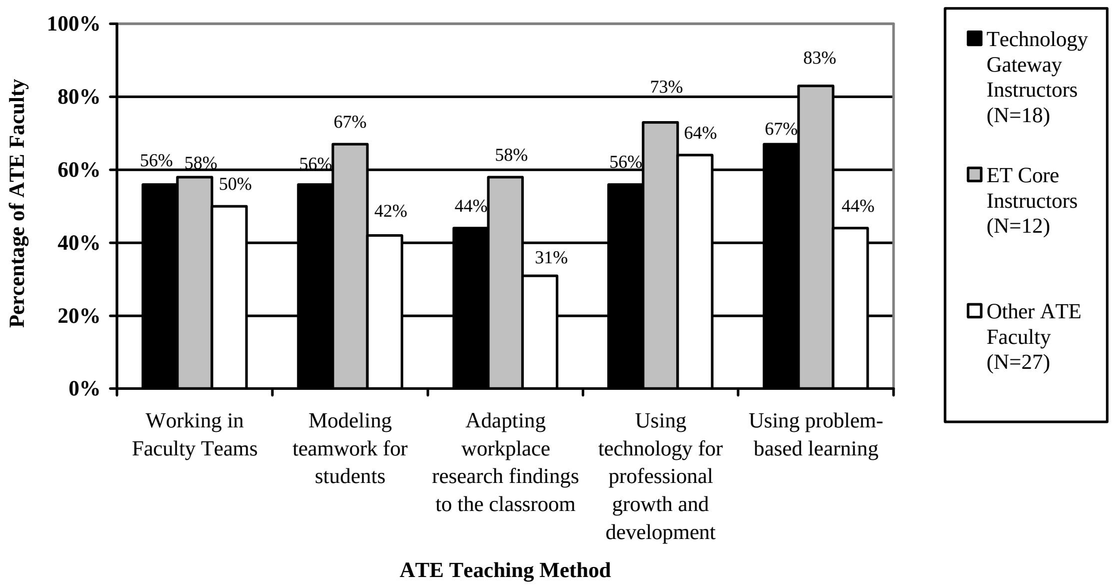
Source: Fall 2000 ATE Faculty Survey.

creating their own problem-based classroom activities based on real-world scenarios. Some instructors mentioned that they were already using ATE methods such as cooperative learning and active learning before their involvement with ATE.

2.2.2.4 ATE faculty disseminate the ATE approach to other faculty, although some non-ATE faculty members remain skeptical.

Over half of ATE teaching faculty members and nearly half of ATE non-teaching faculty members have "provided training for colleagues or information about" the ATE program to other faculty members, according to faculty surveys. ATE faculty were most likely to provide information about problem-based learning with four out of five ET Core faculty members doing so. They were slightly less likely to provide information on using technology for professional growth and modeling teamwork for students while roughly half of teaching faculty provided information on working in faculty teams and adapting workplace research findings in the classroom (see Figure 2-10.)

Figure 2-10. Faculty Survey – Training/Information Provided.



Source: Fall 2000 ATE Faculty Survey.

In telephone interviews, all faculty members mentioned that they disseminate ATE ideas to their peers. In spite of this communication, a significant portion of non-ATE faculty members are "set in their ways" and are not interested in learning or adopting ATE teaching methods, according to faculty interviews and site visits. There seem to be two main reasons for this dissent. First, some non-ATE faculty members, particularly those in the hard sciences, worry that the ATE program will "soften" the intellectual integrity of their academic discipline. They are concerned, for example, that student teamwork may not be the best way for students to learn or for teachers to teach.

Second, other non-ATE faculty members are deterred from adopting the ATE approach by the amount of time ATE faculty spend in preparation and instruction, several ATE faculty members posited. Some mentioned that it might be easier for non-ATE faculty members to adopt small, discrete concepts such as learning styles because "change is hard to accept and to implement."

2.2.3 Other methods used for faculty development

Listservs and ATE Roundtables via TechNet (distance- learning network) are currently being used by ATE faculty as part of their training. An ATE Roundtable is a peer-to-peer faculty development sharing session with ATE faculty providing content and leading interactive discussion.

2.3 Program improvement

The SC ATE Center has worked to increase the number of students enrolling in ATE courses and participating in ATE services through improvements in communications and marketing as well as development of ATE scholarships and internships.

2.3.1 Communications and marketing

ATE publishes a quarterly newsletter – the "ATE Briefs" – in order to disseminate information about the program. ATE has also developed a video for the same purpose. In South Carolina, and in several other states, the SC ATE Center of Excellence staff has delivered presentations on the SC ATE approach. Further, the Center has published a monograph on retention of engineering technology students and number of professional articles, printed recruitment brochures and posters, and developed an ET careers page on the scate.org website.

Over the past two years (since September, 1999), SC ATE Center has disseminated the program information in the following ways for various audiences:

SC ATE Scholars Brochure	439	
SC ATE Retention Monograph	427	
Recruitment Posters	2,146	
Recruitment Brochure	26,539	
General Information Brochure	5,304	
ATE Briefs	600	mailed per quarter (another 500 printed for exhibit and miscellaneous distribution)

2.3.2 Scholarships and internships

2.3.2.1 ATE Scholars Initiative

Selected by business leaders, ATE scholars work as technicians in local industry and receive a full-tuition scholarship and book stipend, equivalent to $2,800 to $3,000 per year. Businesses also donate $500 per year to college trust funds to join an ATE Scholars consortium. The college uses these donations to support recruitment and student recognition activities. Because of the strong connection between the ATE approach and industry needs, businesses have been willing and often eager to provide students with scholarships and work experience, thereby enabling many students to attend college who might otherwise drop out.

ATE partnerships with local industry and banks raise significant funds for ATE scholarships each year. In fall semester 2000, the South Carolina Technology Alliance and the South Carolina Department of Commerce endorsements of the SC ATE program helped jumpstart the ATE Scholars initiative, making it possible for 36 students at four colleges – or one-third of all students in the fall 1999 and fall 2000 ET Core cohorts – to participate in the ATE Scholars program. In total, the ATE Scholars program raised over $100,000 of new scholarship money for engineering technology students during the 2000-01 academic year.[15]

2.3.2.2 Other scholarships

The SC ATE Center has arranged for low-income high school students enrolled in the Technology Gateway through a partnership between Piedmont Technical College and the Newberry Career Center to receive scholarships. A local bank has supported this partnership by providing scholarships to cover the college tuition for students eligible for free or reduced-price lunches. All other ATE students in the class are reimbursed by the bank for their college tuition expenses if they earn grades of B or better in ATE classes.

2.3.3 Program improvement evaluation measures

The number of institutions offering the ATE curriculum per year, the number of ATE courses taught, and the number of SC ATE and industry-provided scholarships are summarized in Table 2-5.

[15] The smallest annual value of an ATE scholarship ($2,800) multiplied by the number of ATE scholarships awarded in 2000-01 (36) equals $100,800. See Section 1 for a discussion of the importance of financial aid to an engineering technology student's chances of graduating with and associate's degree.

Table 2-5. ATE curricula, courses, and scholarships offered, 1998-2002.

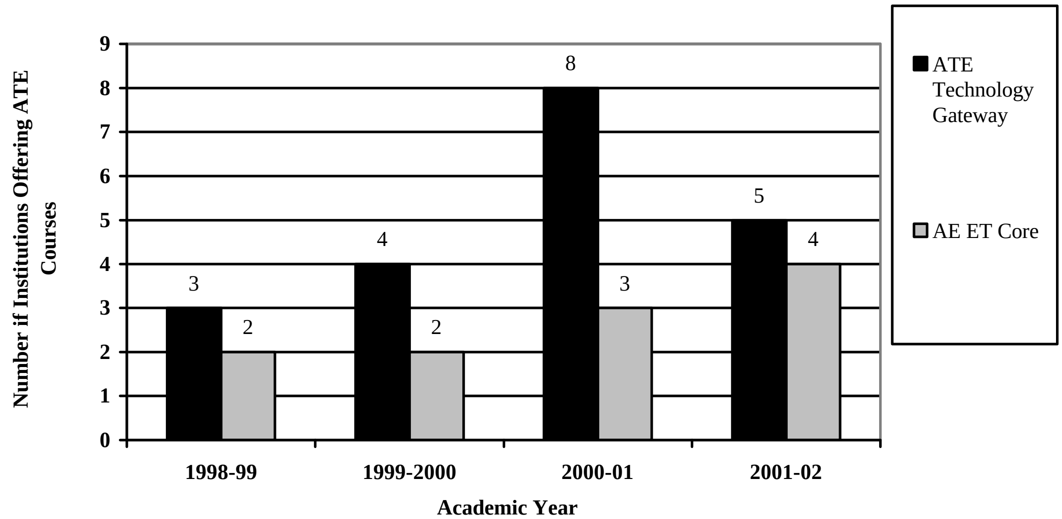
		1998-1999	1999-2000	2000-2001	2001-2002
Institutions offering ATE curriculum (see Figure 1-1and Table 2-6)	Technology Gateway	3	4	8	5
	ET Core	2	2	3	4
	Total	5	5	8	6
Total Number of ATE courses taught *		28	31	66	69
Number of industry-provided scholarships with paid work experience		N/A	18	36	18
Number of SC ATE scholarships		N/A	N/A	147	105

* These numbers include Technology Gateway and ET Core, accounting for the different number of courses taught per offering (e.g., Technology Gateway is 3 classes, 181 & 182 ET Core are 4 classes each, and 183 ET Core is 3 classes) , number of sections offered, and number of colleges offering the sections.

2.4 Evolution of SC ATE

Since 1998, the number of colleges, faculty, and students participating in the ATE program has grown steadily. Figure 2-11 shows the number of institutions offering ATE courses, from fall 1998 to spring 2001, and Table 2-6 shows the evolution of each of the institutions with respect to the incorporation of Technology Gateway and Core Courses by academic year. In addition to this, Figure 2-12 and Figure 2-13 present the enrollment in the ATE Gateway and the enrollment in the ATE Core by college and by academic year.

Figure 2-11. Number of Institutions Offering ATE Courses, fall 1998- spring 2002.



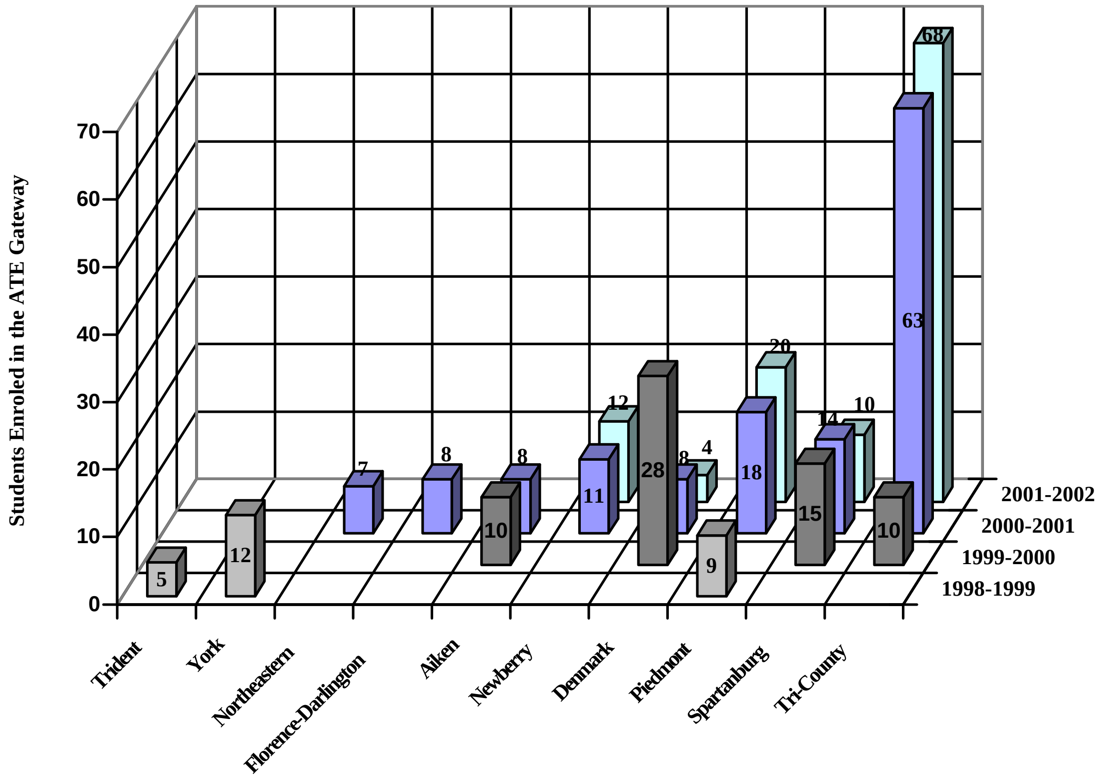
Source: The SC ATE Center of Excellence.

Table 2-6. Institutions Offering the Technology Gateway and the Core Courses by Academic Year.

	Technology Gateway				Technology Core			
	1998-1999	1999-2000	2000-2001	2001-2002	1998-1999	1999-2000	2000-2001	2001-2002
Aiken		X	X					X
Denmark		X	X	X				
Florence-Darlington			X		X	X	X	
Northeastern			X					
Piedmont	X		X	X			X	X
Spartanburg		X	X	X				X
Tri-County		X	X	X	X	X	X	X
Trident	X							
Newberry			X	X				
York	X							

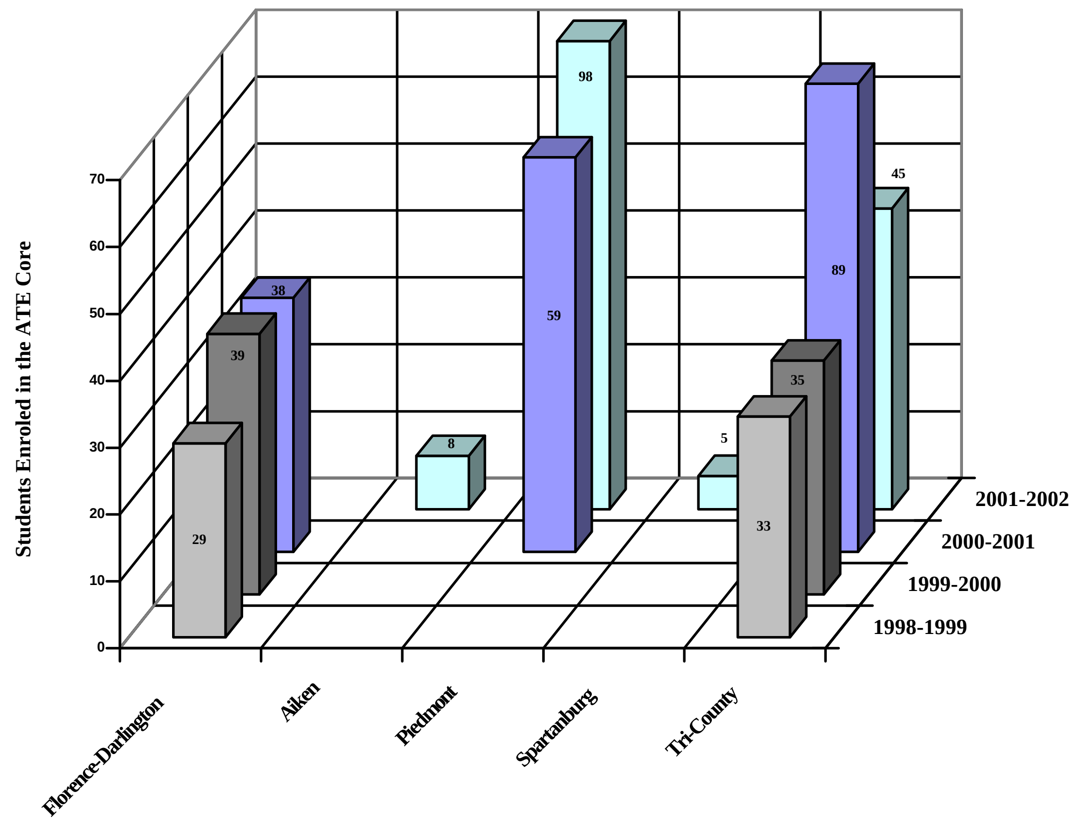
X = Curriculum was offered.

Figure 2-12. Enrollment in the ATE Gateway by College and by Academic Year.



Note: 2001-2002 enrollments are in the back of the graph and 1998-1999 enrollments are in the front.

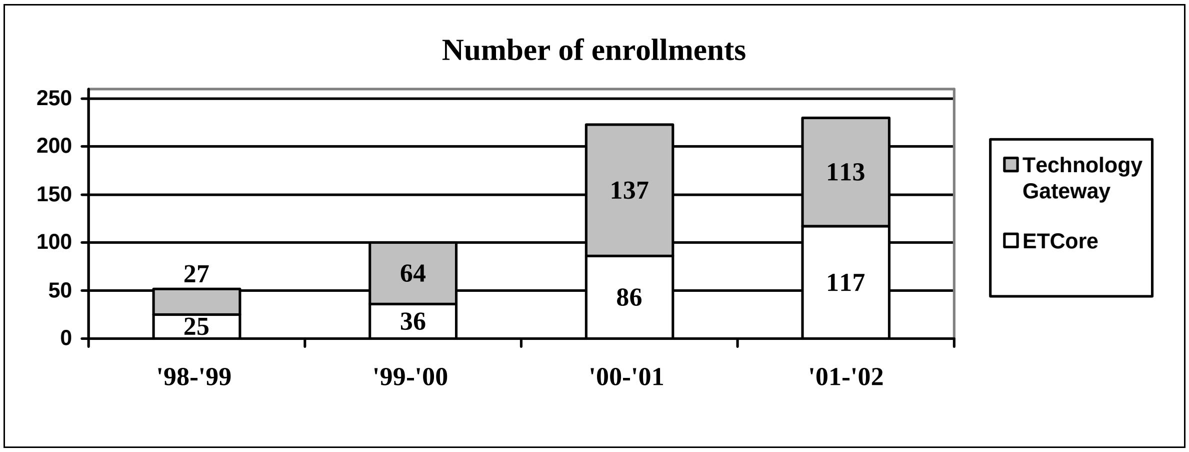
Figure 2-13. Enrollment in the ATE Core by College and by Academic Year.



Note: 2001-2002 enrollments are in the back of the graph; 1998-1999 enrollments are in the front.

Figure 2-14 shows that the rate at which enrollments are increasing – both in the Technology Gateway and in the ET Core – has slowed down in the last year. However, if the current enrollment figures are compared to the ones of the 1998-1999 academic year, it can be concluded that there has been a substantial general improvement in enrollment rates.

Figure 2-14. SC ATE enrollment.



In the 2001-02 academic year, 230 students enrolled in the ATE program, 117 in the ET Core and 113 in the Technology Gateway – over four times the number of students enrolled just three years earlier.

3.0 Student Outcomes

In the process of designing the SC ATE Center's program of systemic reforms and interventions, AED evaluators and State Board for Technical and Comprehensive Education (SBTCE) administrators identified several hypotheses about the outcomes they expected to observe in ATE students while undertaking the ET Core curriculum and after completing the ET Core.

Quality outcomes expected:

- Students will be more engaged in ATE courses than in non-ATE courses.
- Students will develop greater problem-solving skills in ATE courses than in non-ATE courses.
- Students will develop greater communication and cooperation skills in ATE courses than in non-ATE courses.

Quantity outcomes expected:

- Students will be more likely to complete general education courses, and thereby subsequently to graduate, in the ATE program than in the traditional ET program.

Diversity outcomes expected:

- Underrepresented minorities and women will be more likely to enroll in the ATE program than in the traditional ET program.
- Underrepresented minorities will be just as likely as Caucasians to complete ATE courses.
- Women will be just as likely as men to complete ATE courses.

To answer these and other questions, AED evaluators conducted site visits, administered a faculty survey, administered beginning and end-of-semester student surveys, interviewed faculty and students, reviewed ATE materials and education research, and analyzed historical and ATE student records. In Chapter 3 we summarize our findings on the outcomes that ATE students achieved and the evidence in support of each claim.

3.1 Quality outcomes

3.1.1 ATE students tend to be more engaged in their studies than students in comparable non-ATE courses.

The applied nature of the coursework in the SC ATE curriculum helps students see the relevance of general education courses such as communications, mathematics, and science to their careers, makes difficult concepts more comprehensible, and motivates students to succeed[16]. As some ATE students expressed, “all of the subjects tie in together” and “learning seemed easier and more fun.”

The high level of ATE student engagement is evident in increased student-student interaction, student-faculty interaction, and demonstrations of student maturity, all of which are described in the subsequent three sections.

[16] Traditional disciplinary, lecture-based English, mathematics and physics courses do not interest engineering technology students as much as ATE courses, according to interviews and site visits; students tend to perceive these courses as too theoretical, as too difficult, or as irrelevant to their careers.

3.1.1.1 Students interact with each other more in ATE courses.

Because of the emphasis on student teamwork and active learning, ATE students build relationships with their peers, giving them encouragement and support. Student teaming helps students understand difficult concepts and makes learning more enjoyable, according to both students and faculty (see Box 3-1). Students added that their relationships with fellow ATE students extend to other classes where they are more likely to work in teams, even though traditional instructors do not always encourage doing so.

Box 3-1. Comments by students about student-student interaction.

Following are some representative comments from students about the effects of ATE on student-student interaction:

- "Probably more important are the friends you make. You'll learn from them too. I'm in an economics class right now. I don't know anyone's name. I know one guy's called Joshua but I don't talk to anyone. I'm counting the minutes to get out. I have no doubt that it would definitely be better with the ATE approach."
- "We wouldn't be as self-motivated if we had to work alone."
- "Teams make big assignments a lot easier."
- "Three to four people do better than one. By yourself you have one brain instead of four. [A group of students] can put our own answers together and make better answers."
- ATE is "easier. There are more ideas. You can be more creative. You can bring more ideas to the table. You can look at it [a problem] in different ways."
- "Students may walk out of their first year with less stuff in their brains [but] I never saw study groups before ATE. [ATE Instructors] could leave the room and [students] will still be working."
- "Without student teams, slackers wouldn't get anything right, wouldn't learn anything. At least with the team, they learn something.[17]"

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[17] A few students and faculty mentioned that group work has the potential downside of encouraging "free riders" or that it might allow students to rely on their strengths at the expense of learning new skills. This concern, however, was not mentioned frequently. It was evident during evaluator site visits that most students were actively and genuinely participating in group work. At nearly every college, evaluators discussed with students the extent to which they were allowed to rely on their strengths rather than develop new skills. In each case, students pointed out that a student with a unique strength helped other students in the group to learn, rather than carrying the weight of the group.

3.1.1.2 Students and faculty interact more with each other in ATE courses.

The participation of multiple faculty members and the emphasis on problem-based learning boosts student interaction with faculty members. As instructors transform from lecturer to "coach," as faculty members cooperate through integrated courses rather than teach in isolation, and as students change from passive observers of lectures to active participants in projects, students take on more responsibility for their learning and faculty members take on more responsibility for student success.

In problem-based learning, the responsibility to gather and interpret information rests with students. As a result, ATE students tend to take control of their education and to feel more comfortable interacting with instructors. In interviews, nearly all instructors said that ATE students are more likely than non-ATE students to ask questions both during and after class. In the faculty survey, 48% of ATE teaching faculty indicated that ATE students are more likely than traditional students to use e-mail to contact them or to conduct class work, while no faculty members indicated the reverse was true.[18]

With an interdisciplinary curriculum, multiple faculty members share responsibility for a group of students; it is less likely that a particular student will "fall through the cracks." Instructors tend to spend more time answering questions and giving students individual attention (see Box 3-2).

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[18] Although faculty did not report a higher incidence of ATE students visiting them during office hours, many indicated that their offices were located far from the ATE classrooms and were not easily accessible.

Box 3-2. Comments by students about faculty attention.

During AED site visits, ATE students described the heightened level of faculty attention:

- "Teachers take more time with students. You can see they care that students learn."
- "Professors make it fun. They will take time to show each individual person to make sure they get it rather than just writing on the board."
- "It boils down to having four instructors for each course. The [curriculum] is so integrated, we can go to any of them [for help]."

3.1.1.3 ET Core students tend to behave more responsibly and maturely than students in non-ATE courses.

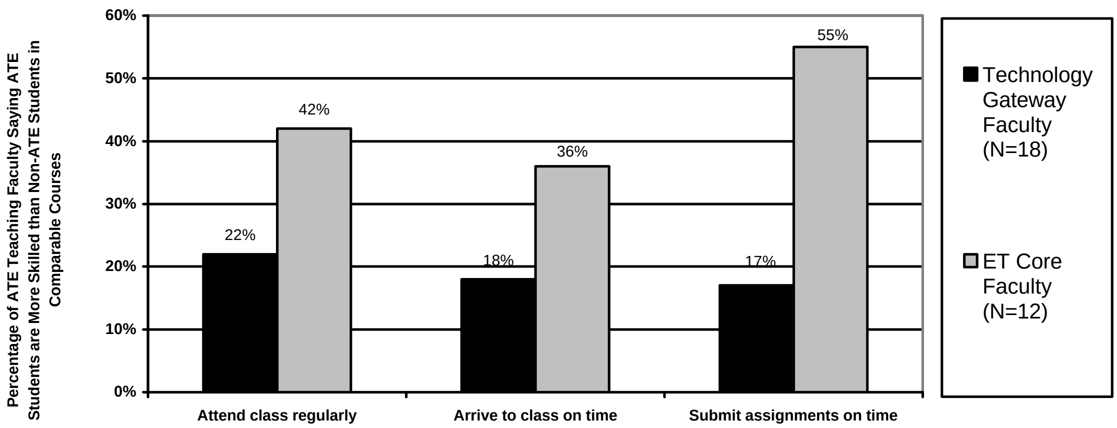
In the ET Core, student teaming, high performance standards – such as minimum grade requirements for ATE Scholars and strict attendance policies – and enthusiasm for the applied nature of ATE coursework, motivate students to meet course requirements and seems to build student maturity. The high cost of missing a block of interdependent courses also motivates students to attend class. Box 3-3 presents anecdotes of how ATE increased the maturity level of two students.

Box 3-3. ATE stimulates maturity.

During telephone interviews, one instructor told a story of an ATE student who came to class, dropped off a paper with classmates, and then walked out of the room. When the instructor confronted her, she said that although she could not stay in class because her son was in the hospital, she needed to contribute her portion of the group project. Another faculty member told the story of a student who decided to drop out of the ATE block of courses during the middle of the semester when he realized he was failing. He continued to participate in class activities, however, until his team members completed their group project, saying he did not want them to score poorly simply because he was dropping out.

By contrast, however, many faculty members noted that Technology Gateway students are immature. Figure 3-1 shows that faculty believe that Technology Gateway students are less likely than ET Core students to attend class regularly, arrive to class on time, and submit assignments on time.

Figure 3-1. Faculty Survey - Compared to the skills of non-ATE students in comparable classes, indicate the level of skill of a typical ATE student on the following:



Source: Fall 2000 ATE Faculty Survey

Possible explanations why Technology Gateway students may be relatively immature are offered in Box 3-4, below.

Box 3-4. Possible explanations about Technology Gateway student's lower maturity levels.

The maturity that is necessary for Technology Gateway courses – i.e., students taking control of their learning, acting independently, and being responsible to their peers – does not match with Technology Gateway students' initial maturity or academic levels:

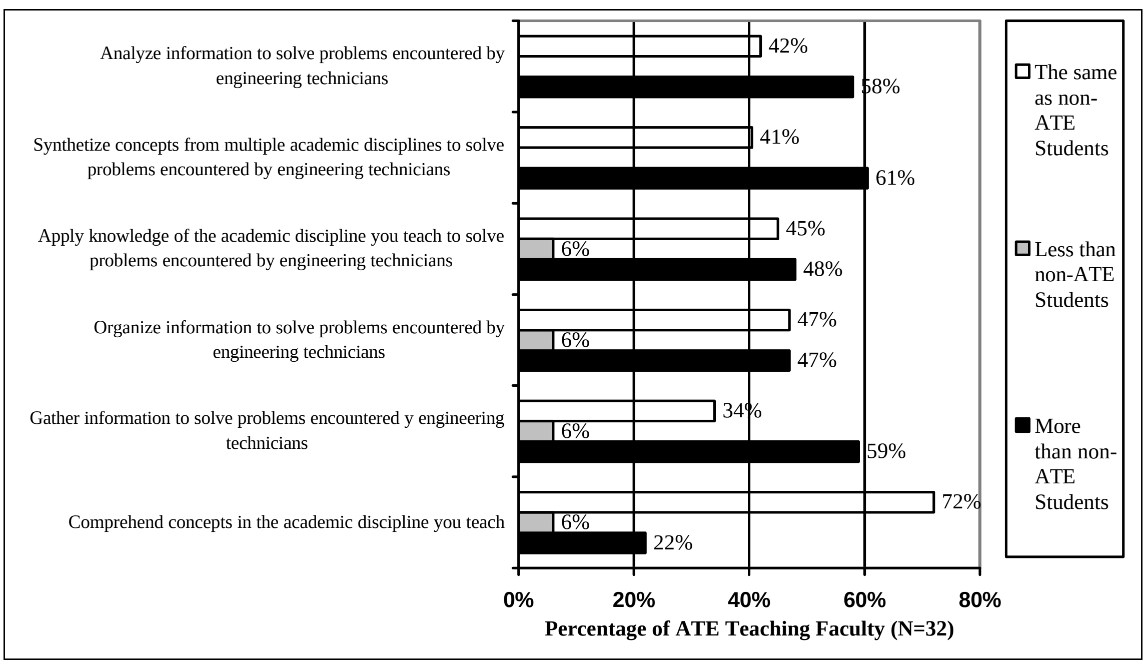
a) Technology Gateway students may be less mature than other students a priori.
   - They are at a lower academic level than ET Core students and they are younger, on average.
   - The demands of the ATE program may simply expose their immaturity.

b) Technology Gateway students' academic level may not match the competencies of the Technology Gateway since the Technology Gateway fits somewhere between developmental studies and college-level courses.

3.1.2 ATE students become better problem-solvers than students in comparable non-ATE courses.

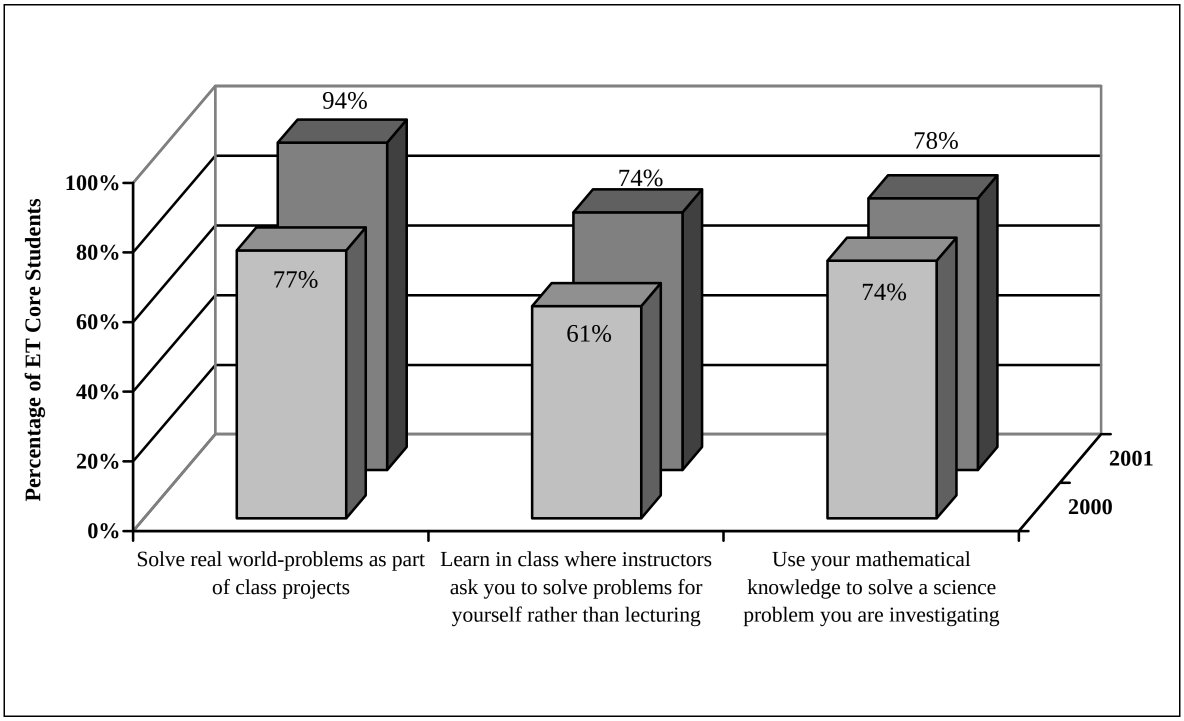
Since the key method of learning in ATE courses is the application of knowledge to solve hypothetical workplace problems, and the key venue for learning is a studio-like redesigned classroom that stimulates the work environment, students get plenty of practice – and develop proficiency – in solving real-world problems. Figure 3-2 shows faculty members' perception of the problem-solving skills acquired by ATE relative to non-ATE students, both current and historical. Apart from conceptual skill or "comprehension of concepts" – with respect to which faculty believe non-ATE and ATE students are equally strong – faculty believe that ATE students typically have better problem-solving skills than non-ATE students.

Figure 3-2. Faculty Survey - Compared to the skills of non-ATE students in comparable classes, indicate the level of skill of a typical ATE student on the following:



ATE students assess their own problem-solving ability as high, as evidenced by findings from student surveys administered in 2000 and 2001. See Figure 3-3, below.

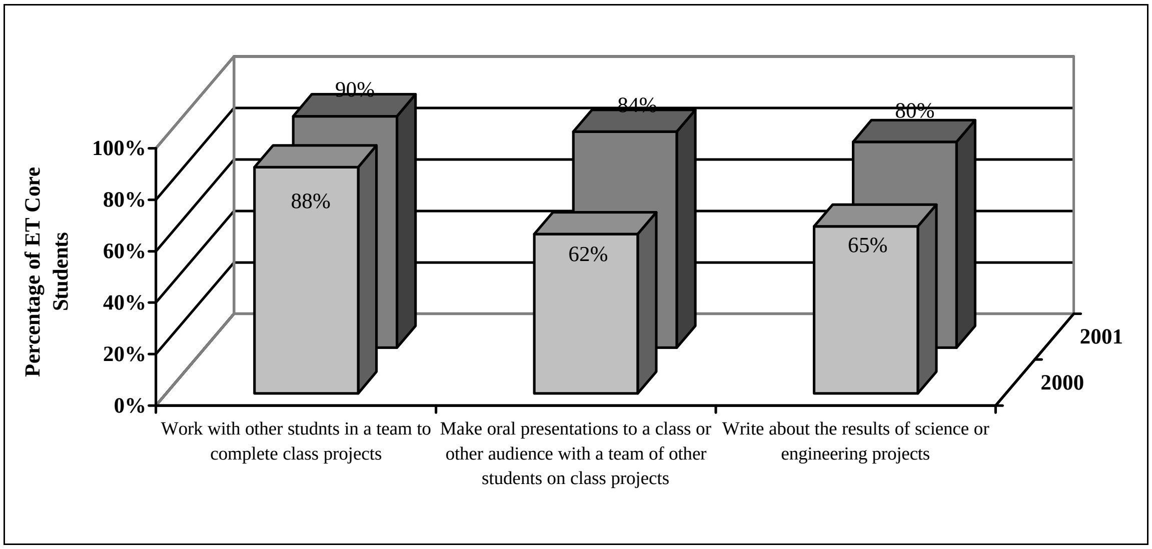
Figure 3-3. Student Survey in 2000 and 2001- Percentage of ET Core students that feel very comfortable in each of the following:



3.1.3 ATE students communicate and cooperate better than students in comparable non-ATE courses.

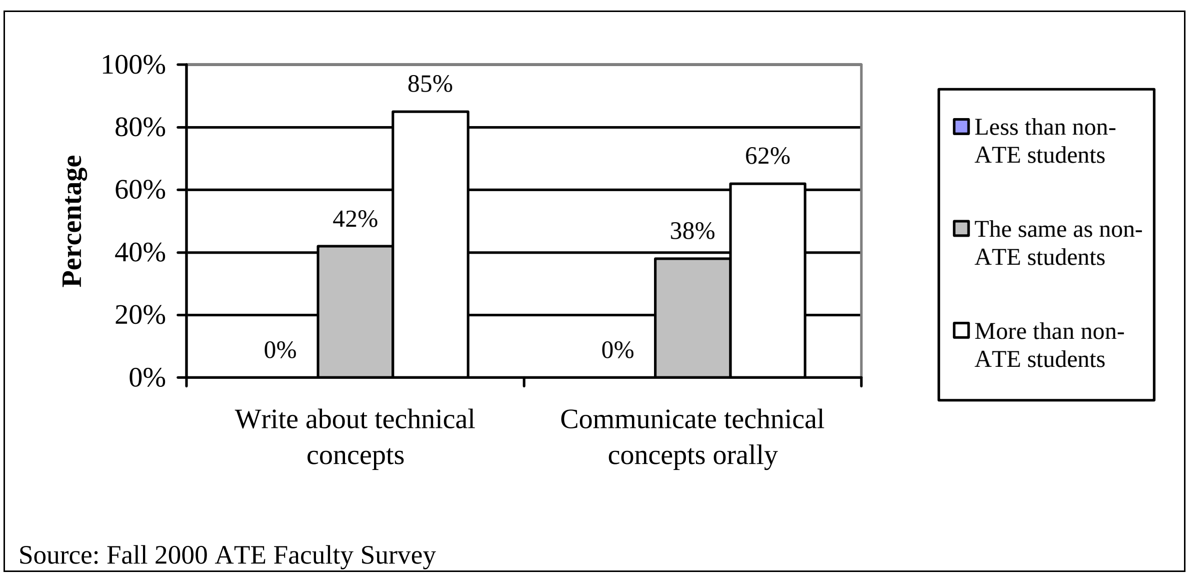
The ATE emphasis on teamwork, multiple intelligences and learning styles, and English and communication projects that are relevant to students' work aspirations develops students' communication and cooperation skills. Several students mentioned during AED site visits that by working in teams with other students with different learning styles, they learned to understand different perspectives. The majority of ET Core students indicated that they feel capable of both working in a team to complete class projects and making oral presentations and writing about the results of projects (see Figure 3-4).

Figure 3-4. Student Survey in 2000 and 2001- Percentage of ET Core students that feel very comfortable in each of the following:



In addition, 62% of faculty indicated that ATE students are better than non-ATE students at communicating technical concepts orally and in writing, while none of these faculty indicated the reverse (see Figure 3-5).

Figure 3-5. Comparison of the level of skills of ATE and non-ATE students.

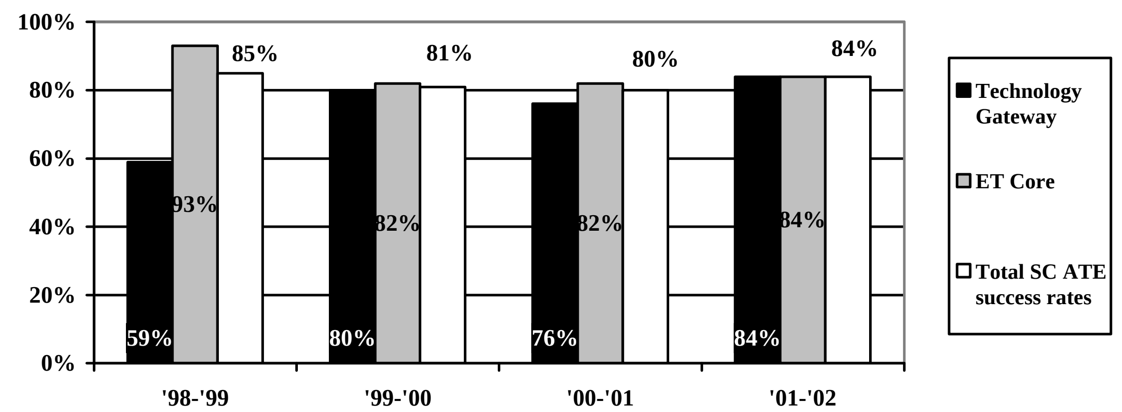


3.2 Quantity outcomes: ATE students persist through program requirements and graduate at much higher rates than students in the traditional engineering technology program.

3.2.1 Course pass rates

Course pass rates are one indicator of student success and likely persistence. Figure 3-6 presents SC ATE courses pass rates for each cohort year.

Figure 3-6. Percentage of SC ATE students that passed their courses.

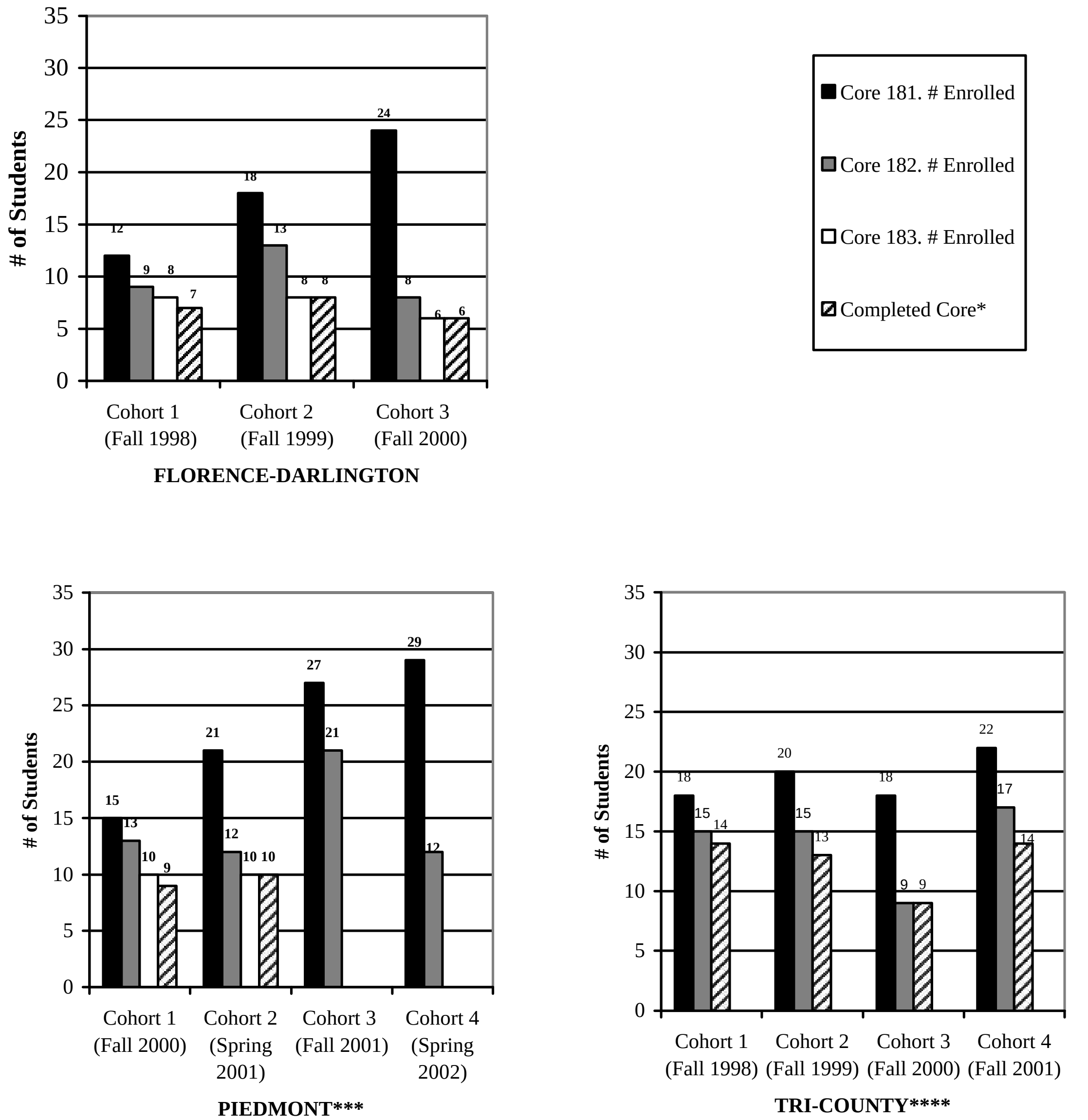


Note: Passing a course is defined as completing the course with a grade of D or better. Flunking a course and dropping-out/stopping-out increases the amount of time the student will need in order to graduate.

3.2.2 Persistence / Completion Rates

Figure 3-7 shows the number of ET Core students by cohort year who passed each core course and enrolled in (i.e., "persisted" into) the following Core semester in three institutions: Florence-Darlington, Piedmont Technical College, and Tri-County Technical College over a four-year period.

Figure 3-7. Numbers of students by cohort year at three state colleges who persisted and completed their ET Core.**



*"Completed core" is defined as having completed mathematics, physics, and English courses with a grade of D or better.

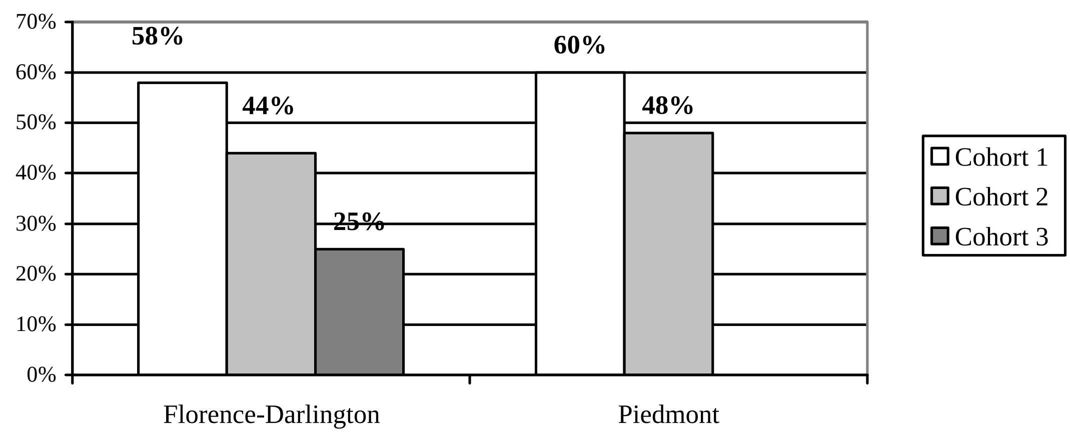
**Persistence indicates the number of students that complete a Core semester and continue with the following one (e.g. Core 181 to Core 182, or Core 182 to Core 183).

***Piedmont has not yet offered Core 183 for Cohort 3 and 4 students.

**** Not all Tri-County students enrolled in the ET Core 181 courses have been required to take ET Core 183 courses. Beginning in 2000-01, ET Core 183 courses were added to requirements for EGT and General ET majors but not other majors. ET Core 183 courses are being added to requirements for EET majors in the 2002-03 academic year.

Figure 3-8 presents the ET Core completion rates in Florence-Darlington and Piedmont Colleges. The ET Core completion rate started out at the 60 percent level with Cohort 1 at both Florence-Darlington and Piedmont Technical Colleges, but declined with Cohort 2 to about 46 percent. Cohort 3 at Florence-Darlington declined to 25 percent which is below the 35% ET persistence rate[19] provided as a historical baseline by two ATE colleges. This downward trend in ET Core completion rates in recent cohort years needs to be studied to determine the trend's contributing factors.

Figure 3-8. ET Core completion rates of students in two state colleges.*



* Percentage of students that have completed the three semesters of the ET Core (181, 182, and 183).

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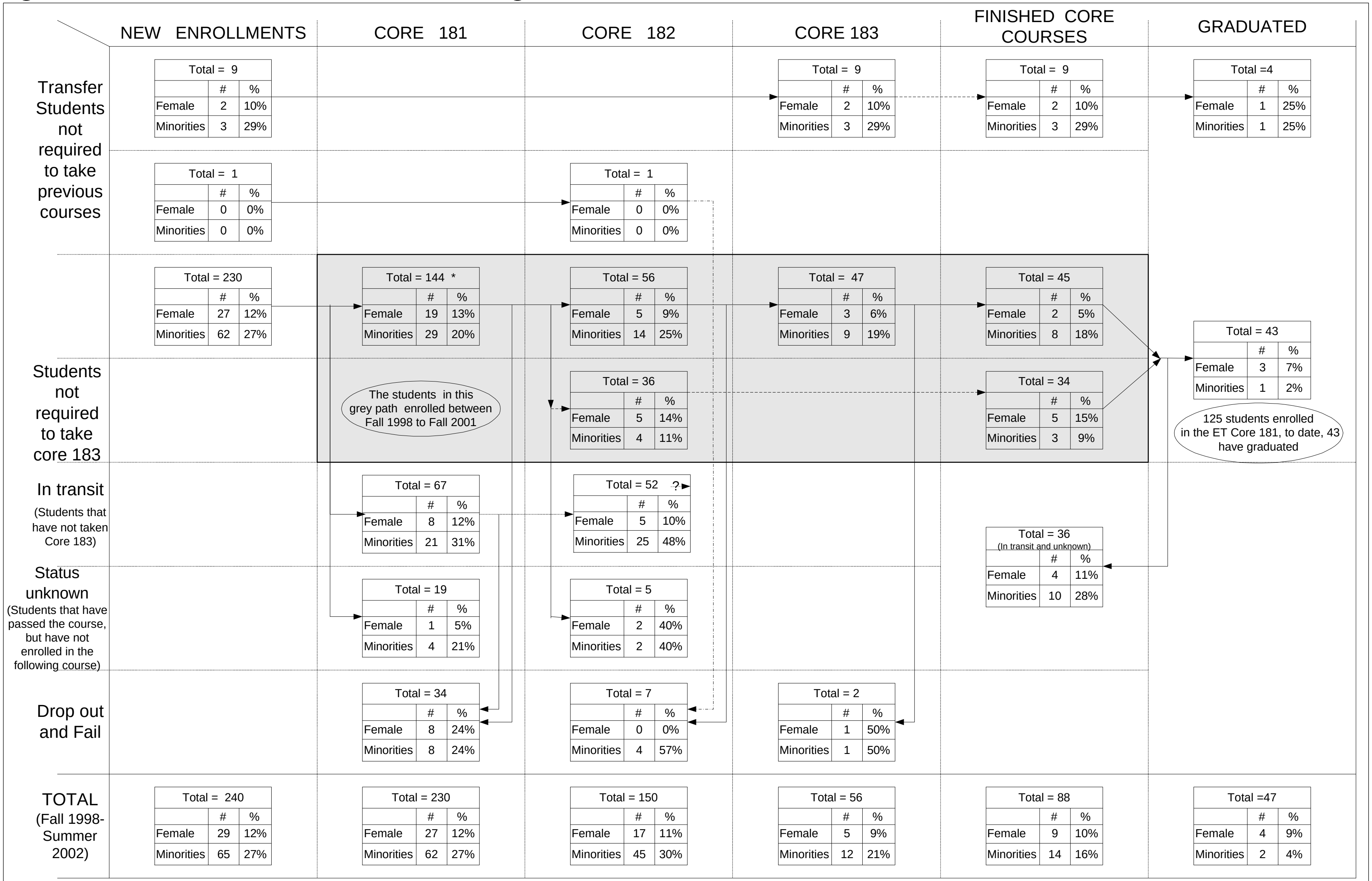
[19] This rate (35%) is the overall persistence rate of ET students to 200-level courses between 1995 and 1996 at Florence-Darlington and Piedmont Colleges. The ET Core replaced the first year of the traditional two-year Engineering Technology program.

Figure 3-9 maps the flow of all ET Core students (all institutions and all cohorts) through the three-semester Core curriculum. It also shows the persistence and drop-out decisions made by all SC ATE students along the ET Core path.

The Academy's analysis of retention and graduation rates of SC ATE students considers only those students who have taken the grey course path. This path encompasses all SC ATE students who had a chance to complete the three Core semesters in the SC ATE program. Since the first Core 181 was administered in fall 1998, and the last Core 183 was administered in fall 2001, the grey path only includes this time frame.

Figure 3-9 shows that 9% of those who finished Core 183 were female (i.e., 7 out of 79). Further, 14% of those who finished Core 183 were minorities (i.e., 11 out of 79). Thirty seven percent of the females who started the ET Core 181 completed the Core 183 (i.e., 7 out of 19). Likewise thirty eight percent of the minorities completed the Core 183 (i.e., 11 out of 29).

Figure 3-9. Flow chart of SC ATE students through the ET Core.



Note: The numbers presented in this chart are a compilation from all students enrolled in Core 181, Core 182 and Core 183 in all SC Technical Colleges for the last four years (fall 1999 - summer 2002). The grey path encompasses those students who by fall 2001 could have completed the core.

Note: "Finished Core Courses" include all students who finished successfully Core 183, and those students who completed Core 182 and were not required to take Core 183.

* Note: The detail for the 144 students is shown in Appendix B.

Table 3-1 shows how the SC ATE program's semester-to-semester retention rate (i.e. from 181 to 182, and from 182 to 183) increased. For example, 92 out of 144 students (or 64% of the students) that enrolled between fall 1998 and spring 2001 into the Core 181 semester continued into Core 182. Seventy nine (79) out of those 92 passed Core 183, an 86% retention rate. Male, white, and female students followed this increasing retention rate. Minority students' semester-to-semester retention rate, however, remained stable and did not increase in this way.

Table 3-1. Generalized retention rates.*

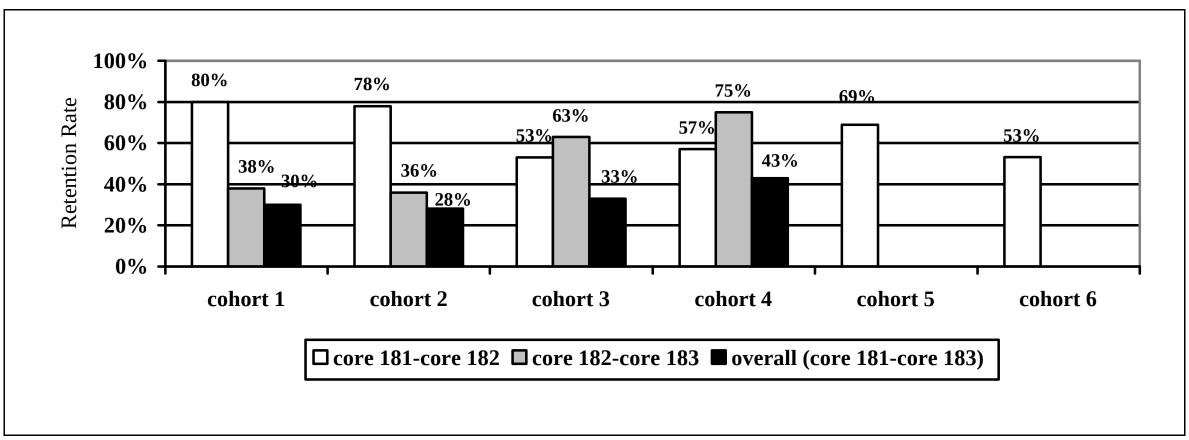
	Core 182 vs.Core 181 students			Students who passed the Core** vs. Core 182 students.			Students who passed the Core** vs. Core 181 students (TOTAL).		
		Number of students	Retention rate		Number of students	Retention rate		Number of students	Retention rate
Female	Core 182	10	53%	Passed C183	7	70%	Passed C183	7	37%
	Core 181	19		Core 182	10		Core 181	19	
Male	Core 182	82	66%	Passed C183	72	88%	Passed C183	72	58%
	Core 181	125		Core 182	82		Core 181	125	
Minorities	Core 182	18	62%	Passed C183	11	61%	Passed C183	11	38%
	Core 181	29		Core 182	18		Core 181	29	
White	Core 182	74	64%	Passed C183	68	92%	Passed C183	68	59%
	Core 181	115		Core 182	74		Core 181	115	
TOTAL	Core 182	92	64%	Passed C183	79	86%	Passed C183	79	55%
	Core 181	144		Core 182	92		Core 181	144	

*Only includes the students in the grey path of Figure 3-9.
**For this analysis, students who passed the Core are those students who completed Core 183 successfully, including the group of students who completed Core 182 and are not required to take Core 183.

Historically, women in the South Carolina technical college system have been more likely than men to graduate with ET degrees once enrolled in an ET program. After four years of enrollment in an associate degree program in the engineering technology cluster, 10% of women typically have graduated, compared to 8% of men.[20] At the end of the first year of the ET program, however, as demonstrated by ET Core completion rates (female: 37%, male: 59%), male students are performing and progressing through the program as well or better than female students.

If analyzed from a cohort-to-cohort standpoint, retention rates also indicate an improvement as the program was implemented in succeeding years. Figure 3-10 shows that while the retention rates from Core 181 to core 182 for cohorts one and two decreased (from 80% and 78% respectively) to retention rates of 53% and 57% for cohorts three and four, retention rates from Core 182 to Core 183 increased, from 38% and 36% for cohort one and two, to 63% and 75% for cohorts three and four. The phenomenon of increased 182-183 retention rates in cohorts three and four improved overall retention rate of 43% in cohort 4.

Figure 3-10. Retention rates by cohort.

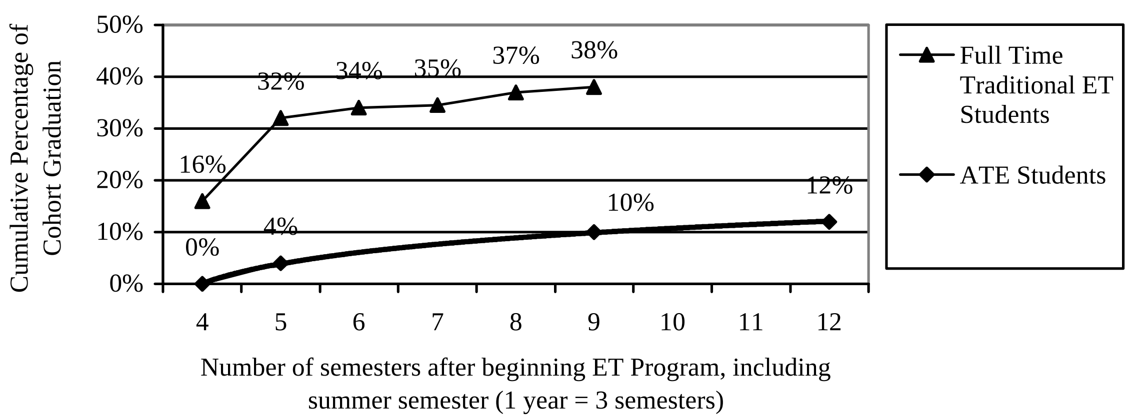


[20] These statistics are based on an AED analysis of all students enrolled in associate degree programs in the Engineering Technology cluster in the 1992, 1993, and 1994 cohorts (N=1614). Both full-time and part-time students are included.

3.2.3 Graduation rates have tripled

Four years after beginning the ET Core, one-third (34%) of ET Core students who completed their Core between fall 1998 and fall 2001 have graduated with associate degrees in engineering technology compared to a historical ET graduation rate of approximately 12%, a rate roughly three times that of the traditional ET students (see Figure 3-11). These improved graduation rates based on preliminary evidence suggest that the ATE approach meets the needs of ET students. These and other improved student outcomes suggest that the increased levels of student engagement (noted in Section 3.1.1), the availability of ATE scholarships (mentioned in Section 2.3.2), and the applied approach to general education (described in Sections 2.1.2.1- 2.1.2.4), combine to motivate students, help them to pay for college, and enable them to master difficult material, and thereby complete their degrees more successfully than their traditional ET counterparts.

Figure 3-11. Graduation Rates of ATE and Traditional ET Students.



Source: Traditional students include all students enrolled in (1) an associate degree program (2) in the engineering program cluster, and (3) in the 1992, 1993, or 1994 cohorts and recorded in the State Board for Technical and Comprehensive Education database (N=1614). ATE student data include all those who enrolled in Core 181 and could have graduated by summer 2002 in at least four semesters (N=125).

Figure 3-9 (p. 53) shows that 16% (i.e., 3 out of 19) of the women who enrolled and finished their Core between fall 1998 and fall 2001 graduated, while 32% (i.e., 40 out of 125) of male students graduated. These graduation rates are very high if compared to the historical female and male graduation rate averages of 10% and 8%. However, the SC ATE program seems to have inversed the historical trend of female having higher graduation rates than men. As for minorities, only 3.5% (i.e., 1 out of 29) graduated, compared to 37% (i.e., 42 out of 115) of whites. The white student results are outstanding if compared to the historical white students' graduation rate average of 10%. However, African-American historical graduation rate (6.5%) still exceeds the SC ATE program's result.

3.3 Diversity outcomes

3.3.1 ATE student enrollment is slightly less diverse than student enrollment in traditional ET programs.

In theory the ATE approach is designed to embrace student diversity (see Box 3-5).

Between the 1992-93 and 1998-99 academic years, an average of 20% of all engineering technology degree students were minorities. The SC ATE program has made an effort to increase minority participation; the Technology Gateway has managed to do so in the last four years, yet it has decreased to a point (27%) where it does not differ significantly from this historical average. The ET Core started very slowly but has managed to increase its minority participation, in the last two years, to a higher level (38%) than that of the Technology Gateway (22%), and that of the historical ET program average (20%) (see Figure 3-12).

Box 3-5. The broad scope of the ATE curriculum may help "open the door" to women and minorities.

While the ATE program is not designed to benefit one group of students over another, certain aspects of the ATE approach might particularly serve women and underrepresented minorities:[21]

- The extra attention afforded to ATE students, through student teamwork and the presence of multiple faculty members, strengthens the connections of women and minorities to classes typically dominated by Caucasian men.
- Through the application of multiple intelligences and learning styles theory, ATE lessons are designed to engage students from a variety of backgrounds.
- Integrating engineering courses with English and communications – subjects in which women typically outscore men –may engage more women in technical studies.

Figure 3-12. Minority participation in the SC ATE program.

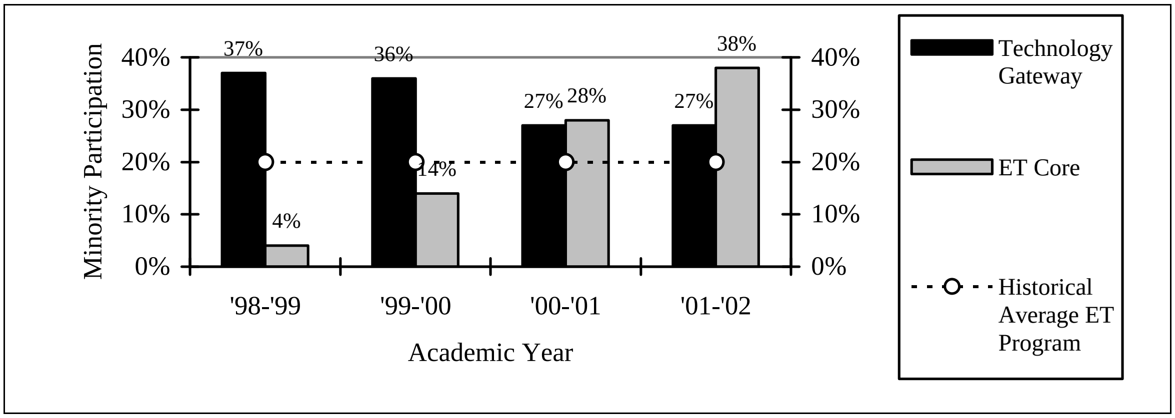


Figure 3-13 shows the steady increase in African-American enrollments in both the Technology Gateway and the ET Core over the past four years.

[21] Faculty members at one college mentioned that their colleagues were concerned that the ATE program was "some kind of affirmative action program."

Figure 3-13. Minority increase in the SC ATE program.

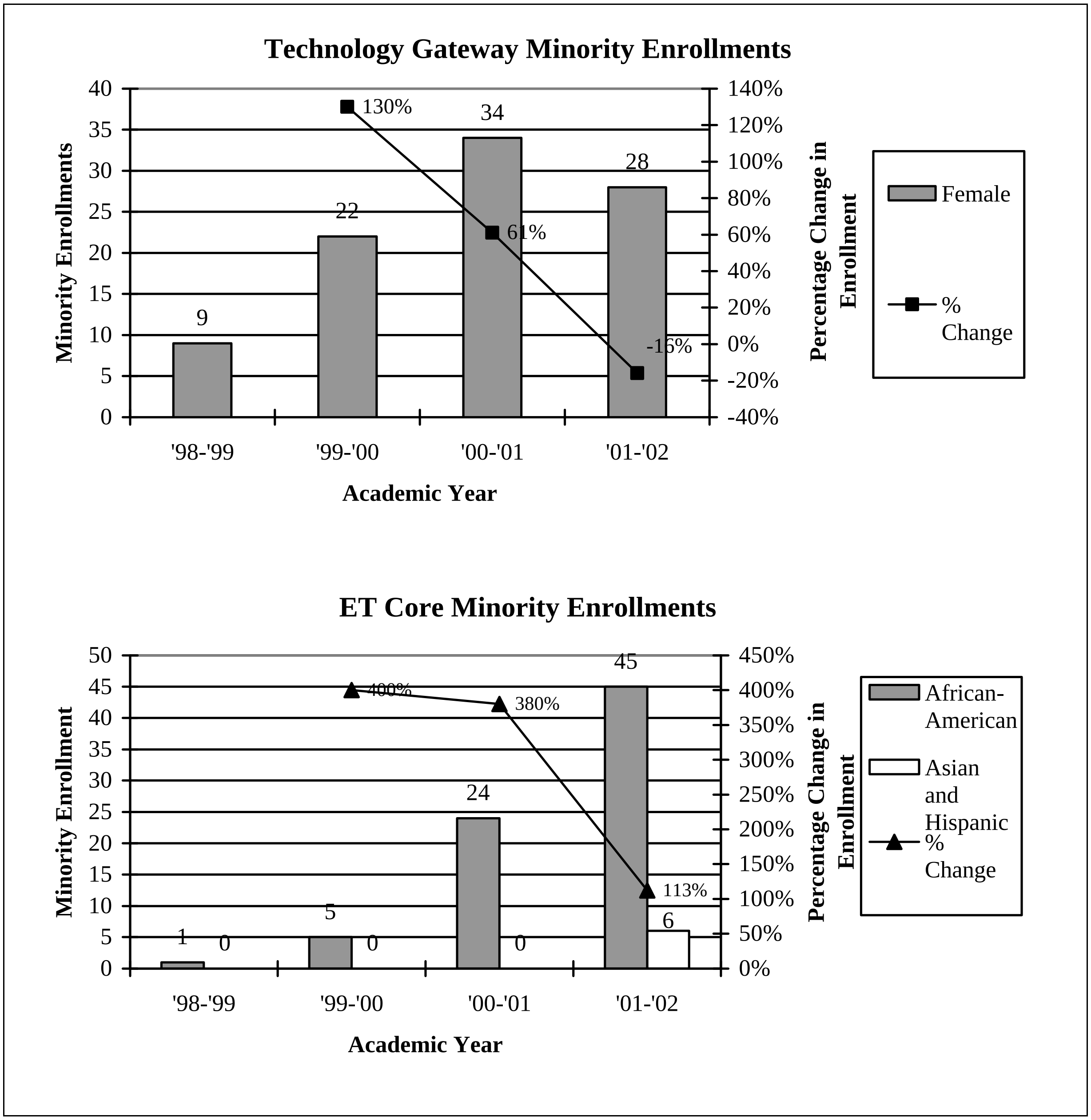
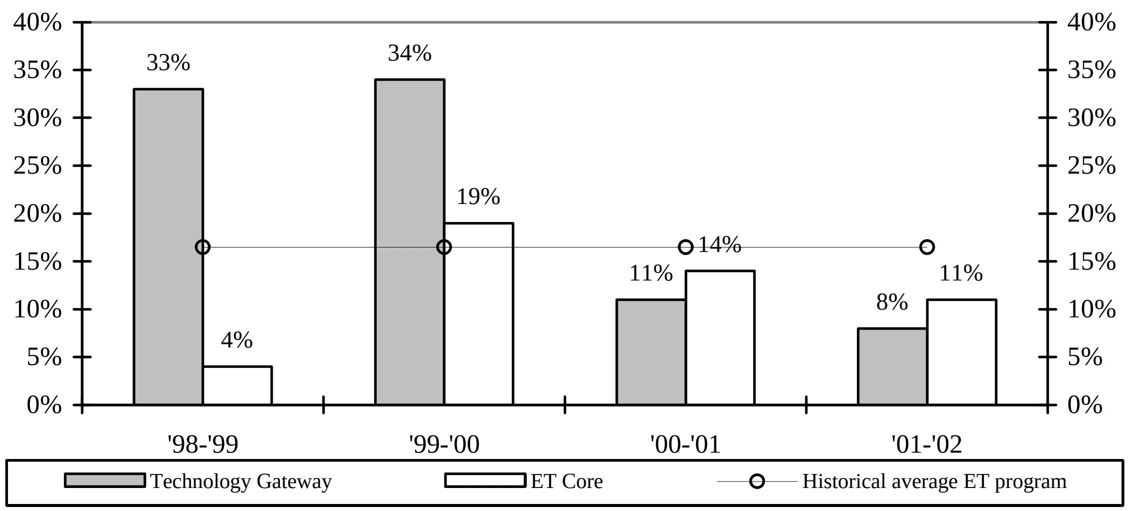


Figure 3-9 (p. 53) shows two general minority enrollment figures. The first, which only encompasses students in the grey path, indicates that from fall 1998 to spring 2001 twenty percent of the students who enrolled the SC ATE program (Core 181) were minorities. However, if those students who have not finished the Core because the courses had not yet been offered are included (from fall 1998 to summer 2002), the percentage of minority enrollments increases to 27% compared to the 20% historical average.

Female enrollment in the ATE program shows no increase over historical averages. Female enrollment in the Technology Gateway was strong in the first two years (33%) but dropped to approximately 10% in the last two years (Figure 3-14). Even though the ET Core has increased its female participation in the last three years, it still has lower female participation rates than the historical averages (17%). Approximately seventeen percent of traditional ET students have been female[22], according to the State Board for Technical and Comprehensive Education database.

Figure 3-14. Female participation in SC ATE program.

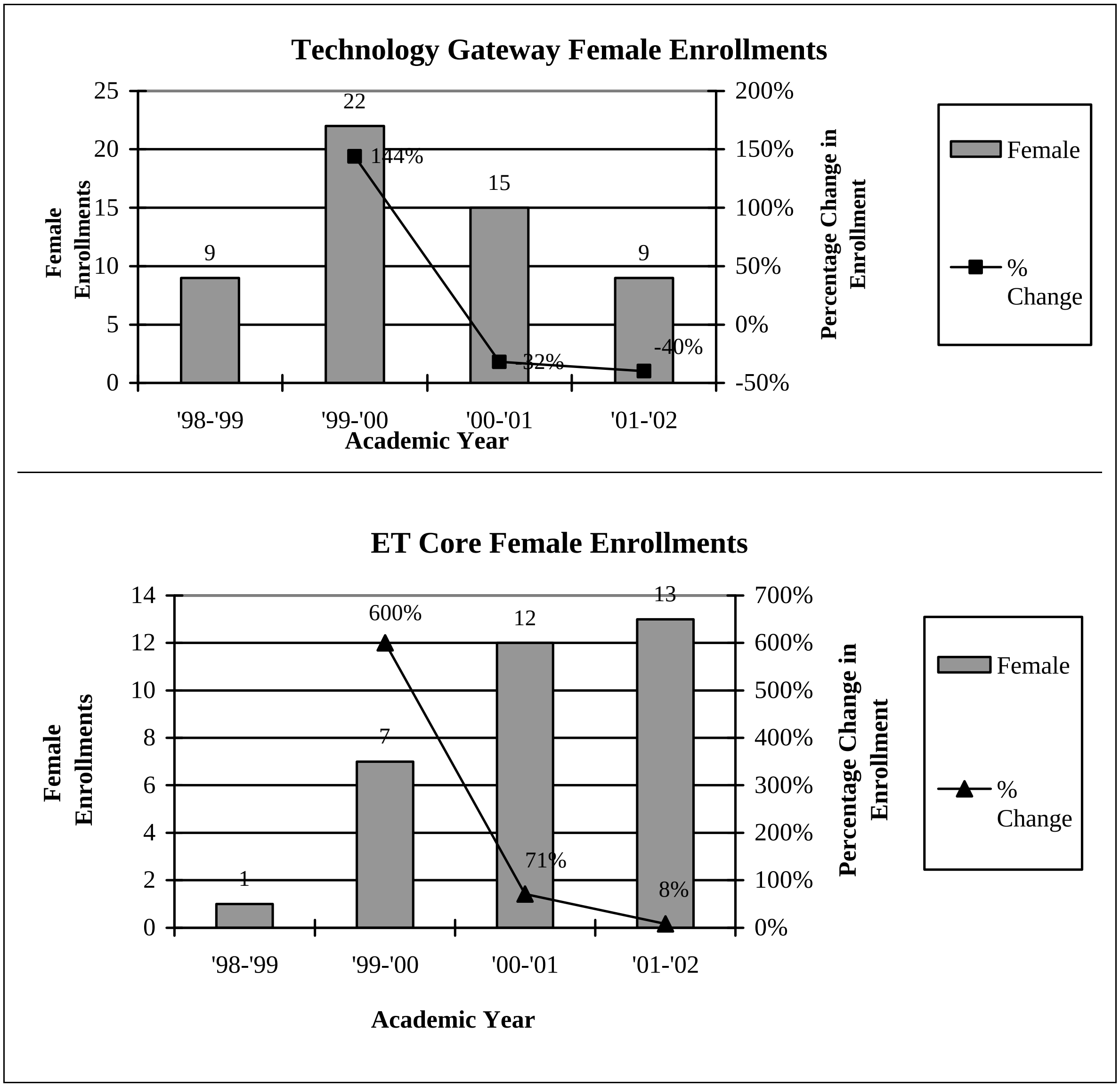


Note: The ET Core is comparable to the traditional ET program; the Technology Gateway, a pre-ET preparation program, is not.

Figure 3-15 shows that the Technology Gateway has had a steady decrease in female student enrollment in the last three academic years (’99-’00, ’00-’01, and ’01-

’02). A contributing factor to this trend was the increased use at several colleges of the Technology Gateway as a course of study for the Industrial Technology major. The Industrial Technology program historically has had a predominantly male student enrollment. Contrarily, the ET Core has increased female student enrollment.

Figure 3-15. Female increase in the SC ATE program.



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[22] Based on all students enrolled in an associate degree program in the Engineering Technology cluster in

Figure 3-9 (p. 53) shows that in both periods analyzed (fall 1998-fall 2001 or fall 1998-summer 2002), female percentage of the total enrollment does not exceed 13% (i.e. 19 out of 144 or 27 out of 230, respectively), a much lower rate than the 17% historical average.

3.3.2 Women and minorities are as successful as white males in the ATE program.

To date, neither gender nor ethnicity appears to affect a student's likelihood of completing ATE program requirements. This is significant because, as mentioned in Section 1.2.2, traditionally blacks are far less likely than whites to complete engineering technology degrees.

Figure 3-16 compares the percentage of female students who pass their courses with a grade of D or better (female course-success rates) versus that of males. It should be noted that it is difficult to compare the performance of the two groups with a high level of statistical confidence because of the small sample size of female students.

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the 1997-98 academic year.

Figure 3-16. Male vs. female course success rates.

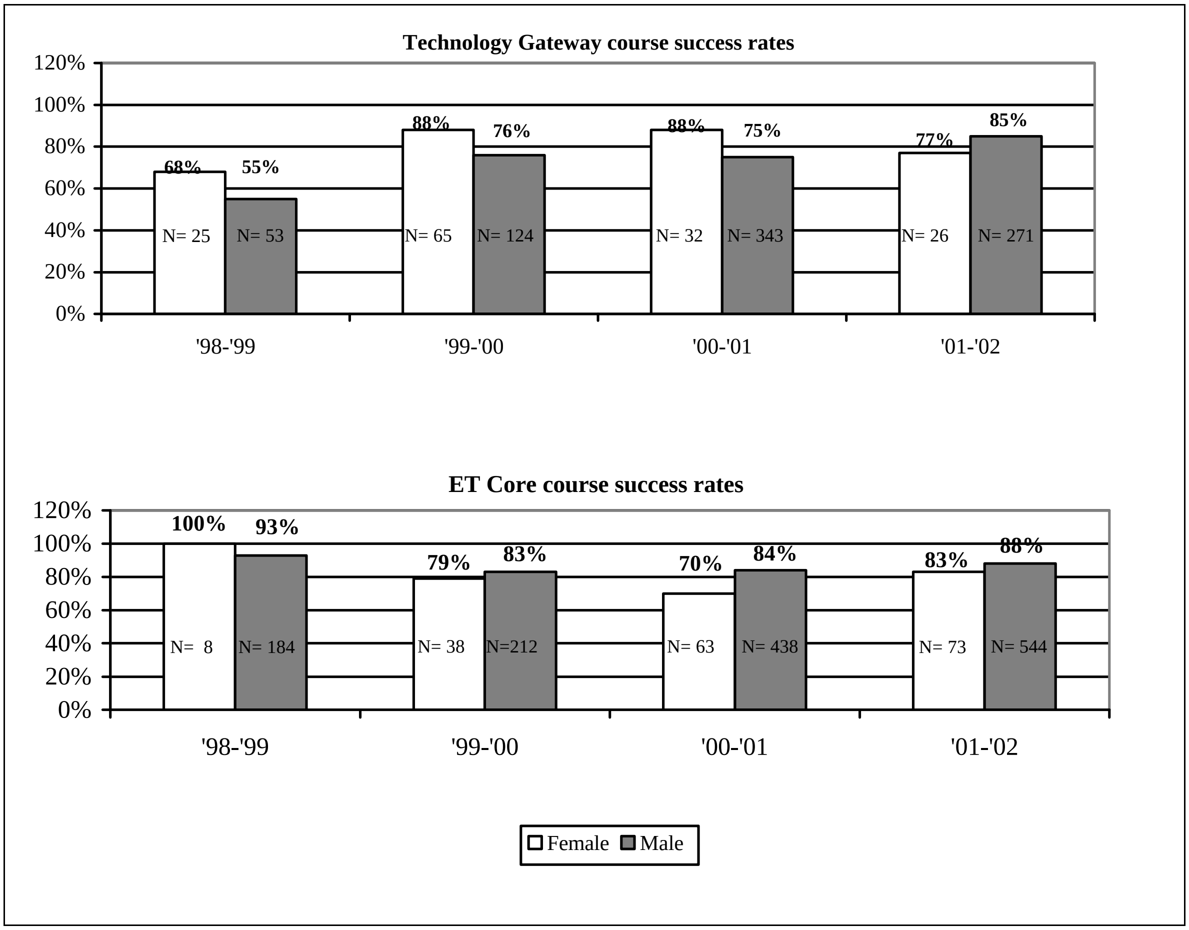
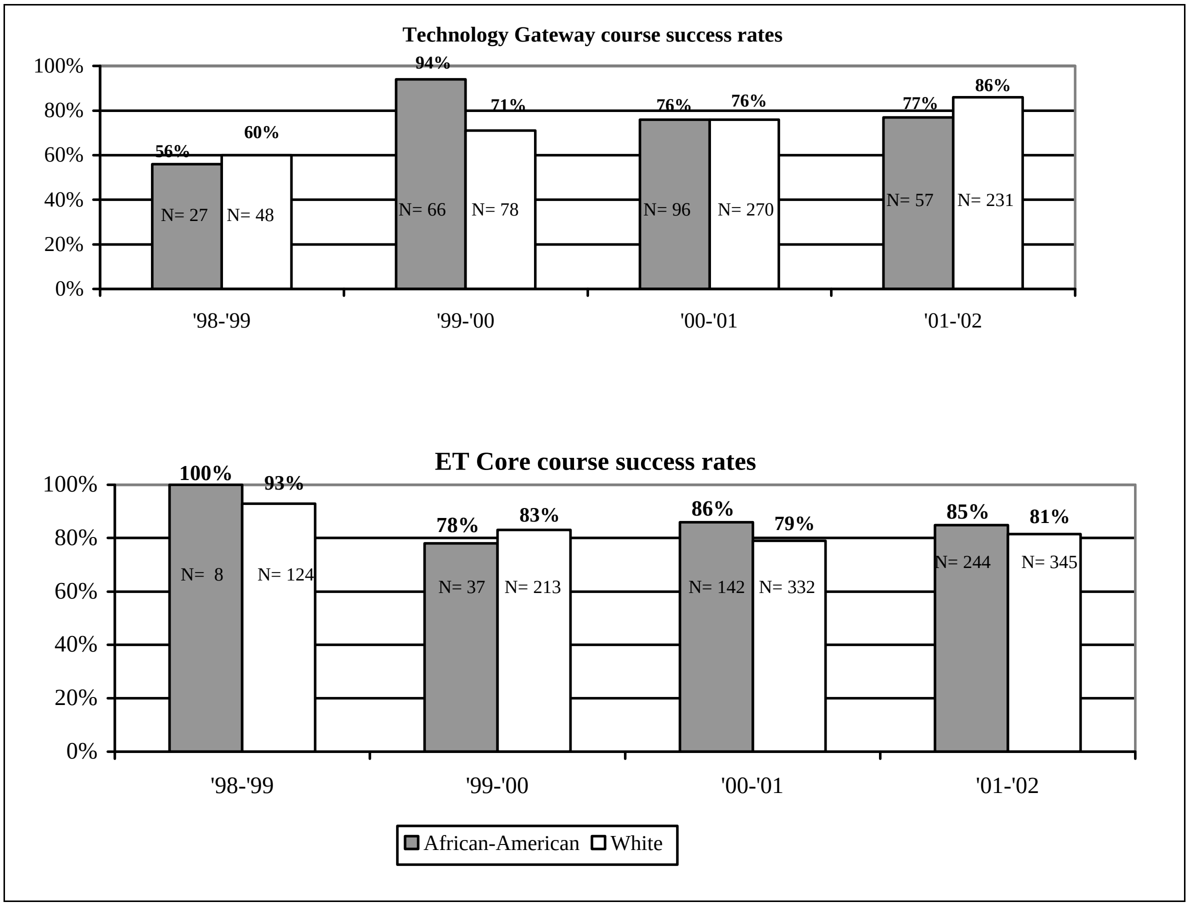


Figure 3-17 compares the percentage of African-American students who pass their Technology Gateway course and ET Core versus that of white students. From these figures, one may conclude that the ATE course success of African-American students is comparable to that of white students.

Figure 3-17. African-American vs. white students' success rates.



4.0 Findings and Conclusions

The following findings and conclusions describe what happened to 144 ET 181 enrolling students over a four-year period.

4.1 SC ATE Center is having a positive impact on the quantity, quality, and diversity of ET students.

The goal of the SC ATE Center has been to increase the quality, quantity, and diversity of South Carolina engineering technology graduates. The Center is succeeding, to varying degrees, in meeting these goals:

Quantity **The ET Core has steadily increased its enrollment in the past four academic years.** In the first year of ET Core implementation, 1998-1999, 25 students enrolled in the ET Core. Three years later (2001-2002), 117 students enrolled in the ET Core (Figure 2-14), an increase of 368%.

The ET Core has increased ET graduation rates by over 300 percent. Over this three-year ET Core implementation period, a total of 230 students enrolled in Core 181, the first semester of the three-semester ET Core. This sample of ATE students, represented by the grey course-taking path in Figure 3-9, provides the best basis for comparison between the ATE approach and the traditional approach of producing engineering technology graduates because these students undertook the ET Core to a sufficient degree[23]. Of those 230 students, 144 students (60%) enrolled in Core 181 by fall 2001. Of those 144 Core 181 enrollees, 125 ATE students could have graduated as early as summer 2002. **By the end of three years or nine consecutive ET Core semesters, forty three of the 125 ATE students have completed the second year of engineering technology courses and graduated (34.4% graduation rate,[24] Figure 3-9), compared to the traditional ET graduation rate average of 10% after three years,** and 12% after four years.

The ET Core completion rates are similar to the first year completion rates in the traditional engineering technology program.

ET Core completion rates (55%, Table 3-1) were very similar to the first year completion rates of traditional ET students (56%, section 2.1.1, p. 15).

Quality **The ET Core provides a sounder foundation for, and increases student success in second-year ET courses.**

The ET Core is more intensive, structured and rigorous than the first year of the traditional ET program, which did not require ET students to take all of the fundamental courses before advancing to the second year of the ET

[23] For purposes of this analysis, students that "finished the ET Core" are defined as those students that (1) completed 181, 182, and 183; or (2) completed 181, 182, and were exempted from taking 183; or (3) completed 183 and were exempted from taking 181 and 182.

[24] These figures only take into account those students who started the ET Core by taking Core 181 (the first semester). Students who were exempted from Core 181 and/or Core 182 were not included in the analysis.

program. Despite its increased rigor, the ET Core's completion rate (55%, Table 3-1) and the first year of the traditional program's completion rate (56%, section 2.1.1, p. 15) are comparable, and the second-year performance of the ET Core completers improved greatly. The ET Core's replacement of the traditional ET program's first-year courses, coupled with the ATE program's other reforms, has worked to boost second-year completion and program graduation rates by 300 percent. In short, engineering technology students who complete the ET Core are three times more likely to complete the program's second-year offerings and graduate than their traditional counterparts.

The ATE approach develops students' "workplace readiness skills" better than the traditional approach to engineering technology education. Students seem to develop greater problem-solving skills, probably because of the ATE emphasis on problem-based learning (section 3.1.2).

The ATE approach also seems to develop greater communication and cooperation skills, probably because of the integration of communications with technical courses and the emphasis on student teaming (section 3.1.3).

Diversity **The SC ATE Program has increased minority enrollments, but minority graduation rates have dropped from historical levels.**

Minority participation in the SC ATE program (27%, Figure 3-9) has exceeded the historical average for ET students (19%, section 1.2.3, p. 10). However, a lower percentage of the minorities in the SC ATE program graduated (3.5%, Figure 3-9) than graduated from ET programs in the past (6.5%, section 1.2.2). In contrast, more whites enrolled in the SC ATE program graduated (37%, Figure 3-9 and section 3.2.3) than graduated from ET programs in the past (10%, Section 1.2.2).

Minorities' retention rate (38%, Table 3-1) in the last four years of the ATE program continued to be lower than white's retention rate (59%, Table 3-1).

Female ET enrollment has decreased in the SC ATE Program from historical levels, but female ET graduation rates have increased.

Female ET enrollment in the SC ATE program (12%, Figure 3-9) is lower than the historical average for female ET students (between 16% and 19%, section 1.2.3). The female ET Core completion student completion rate for students enrolled in the SC ATE program over the past four years (1998-2001) was 37%, whereas the ET Core completion rate for male students was 58% over the same time period (Table 3-1). These rates are comparable to the historical first-year completion rates for all traditional ET students (56%, Section 2.1.1, p. 15). Graduation rates in the traditional ET programs were higher among female students (10% of female graduated, versus 8% of male, Section 1.2.3). In contrast, graduation rates in the ATE program for both females and males have increased, (female: from a 10% historical average to 16% in the SC ATE program; male: from an 8% historical average to 32% in the SC ATE program, Figure 3-9).

There is no significant difference in ET course pass rates by race or gender (Figure 3-16 and Figure 3-17).

Through student teaming, faculty teaming, and alternative instructional methods, ATE may be leveling the playing field between black, female, and white male engineering technology students.

Table 4-1 summarizes the ET Program conditions before ATE was implemented and after the ATE program was implemented.

Table 4-1. Overview of Before- and After-Program Indicators.

			"Before" Traditional ET Program	"After" ET Core-enhanced Program	TREND
QUANTITY	TOTAL Graduation Rates within 3 years		10%	38%	+
	TOTAL Completion Rates		56% (first year)	55%	=
DIVERSITY	Enrollment	Minorities	19%	27%	+
		Female	between 16% and 19%	12%	-
	Retention	Minorities vs. Whites	Historically, minorities have lower retention rates than white students.	Minority students' retention 38% vs white students' retention 59%	=
		Female vs. Male	Historically, female students have higher retention rates than white students.	Female retention 37% vs. male retention 58%	Inverted
	Graduation	Whites	10%	37%	+
		Minorities	6.5%	3.5%	-
		Female	10%	16%	+
		Male	8%	32%	+

4.2 Student, faculty, and employer satisfaction

Students Students report that they learn more and understand concepts better with teamwork and a problem-based curriculum. They see the relevance of learning mathematics, physics, and communications and benefit from hands-on, active learning. *"What we do learn, we learn. We have good retention of it. [ATE is not] memorizing for a test – you actually learn it."*

Faculty Faculty see gains in student performance, depth of understanding, and maturity (particularly in the ET Core). Faculty believe that the SC ATE approach is better for student learning, helps more students succeed, and produces a more workplace-ready graduate. *"They are having to work harder but the outcome is worth it"*.

Employers Employers say the curriculum is better aligned with their priorities and produces technicians who not only have good technical skills but who also can communicate, work in teams, and solve problems. The testimonials of business leaders who have worked with ATE Scholars are very reassuring, since they refer to the program as "the best technical training that our state could offer" as well as "right in line with what industry needs today"[25]. One of them expressed that the ATE Scholar would not hesitate "to take on a problem at a plant. They just dive right in and get it done."

4.3 State and nation-wide dissemination of SC ATE is a sign of success

The SC ATE curriculum is being adapted for implementation by groups both within South Carolina and across the nation. Within South Carolina, the Technology Gateway is being adapted for use as a core of study for industrial technology majors and implemented for dual credit through technical college/high school partnerships. The Technology Gateway is also being taught at night. In addition, SC ATE-supported teaching methodologies and the Technology Gateway curriculum model are being considered for adaptation/implementation by the SC Technical College System's Developmental Studies Peer Group.

Several colleges have established the SC ATE curriculum as the primary curriculum for students majoring in engineering technology. Piedmont, Florence-Darlington , and Tri-County Technical Colleges in particular are engaged in a number of activities designed to institutionalize the SC ATE curriculum and associated teaching methodologies in ways that will ensure sustainability beyond the SC ATE Center of

[25] Quote by Jeffrey Helton, Honda manager of administration from SC ATE Center news brief.

Excellence grant. One strategy being used by all three is preparing a large cadre of trained ATE teaching faculty to enable multiple teaching teams to be assembled as needed over time. Faculty from these colleges will be prepared to deliver additional ATE Teaching Team Training classes locally as needed in the future.

Additionally, Florence-Darlington Technical College, in partnership with Piedmont Technical College, has received a three-year $900,000 National Science Foundation grant to establish a National Resource Center for engineering technology education.

Externally, the Connecticut College of Technology, Kentucky Community and Technical College System, and Delmar College in Texas are actively engaged in projects designed to adapt and implement the SC ATE curriculum model in their colleges. Preliminary plans for adaptation and implementation are also being made at St. Louis Community College Florissant Valley, and two faculty members from that college have enrolled in an April 2001 SC ATE Teaching Team Training Class to be held in Columbia, SC. In addition, the SC ATE Center of Excellence is a partner in two exciting national projects: the Technology Education Improvement Initiative of the Accreditation Board for Engineering and Technology (ABET), and the Blueprint for Change in Engineering Technology Education being directed by the New Jersey Center for ATE.

The SC ATE Technology Gateway and the ET Core curriculum have been published as a curriculum kit in a box and are now available for classroom use nationwide.

5.0 Bibliography

Bernat, G. A. and E. S. Repice (2000). “Industrial Composition of State Earnings in 1958-98.” Survey of Current Business **February 2000**.

Evans, W. D. (2000). Recruitment and Retention of Engineering Technology Students, South Carolina Advanced Technological Education Center of Excellence. South Carolina Technical College System.

Hanson, S. L. and NCES (1996). Lost Talent: Women in Sciences. Philadelphia, PA, Temple U. Press.

Mack, L. G., Mecca, T. V., and Cushing Smith, S. (1998). Shaping Curriculum for Workplace Research. ASEE Annual Conference.

National Center for Education Statistics (2000). Entry and Persistence of Women and Minorities in College Science and Engineering Programs. Washington, DC, US Department of Education.

National Center for Education Statistics (2000). Research and Development Report. Entry and Persistence of Women and Minorities in College Science and Engineering Education.

National Science Foundation (2000). Women, Minorities, and Persons with Disabilities in Science and Engineering: 2000. Washington, DC, National Science Foundation.

Persons, T. (1999). “The Tera-Byte.” South Carolina Technology Alliance **1**(1).

South Carolina Budget &Control Board Office of Research and Statistics (2002). Per Capita Income in 1989. **2002**.

South Carolina Chamber of Commerce (2000). “Skills that Work 2000: A comprehensive Analysis of South Carolina's Workforce, Critical Jobs and Necessary Skills.” .

South Carolina Department of Commerce (1999). “South Carolina Department of Commerce 1999 Annual Report.” : 60.

South Carolina Technical Education System (1997). South Carolina Technical Education System 1997 Factbook.

State Board for Technical and Comprehensive Education (2000). Program Evaluation Report.

6.0 Appendixes

Appendix A – Evaluation Methodology

Appendix B – Core 181 Student Data

Appendix C – Cost-Benefit Analysis Proposal

Appendix A – Evaluation Methodology

AED researchers conducted the following activities between fall 1999 and summer 2002 to evaluate the impact of the ATE approach:

1. Student surveys – AED, in cooperation with the SC ATE Center, drafted beginning and end-of-semester surveys for both Technology Gateway and ET Core students. In fall semester 1999, these surveys were administered by ATE faculty members in ATE classrooms using paper questionnaires. By the end of fall semester 2000, AED converted these surveys to Internet forms supported by MS Access databases. That administration of the survey was supervised by faculty with students completing the survey in computer labs or at computer stations in ATE classrooms. During that administration, 27 of the 86 students enrolled in the Technology Gateway completed the survey for a response rate of 31%. (Note that the actual response rate is likely higher because some of the 86 students may have dropped out by the end of the semester). Of the 57 students enrolled in the first semester of the ET Core, 22 (39%) responded to the survey. A second survey was administered via internet in October 2001.

2. Faculty survey – The SC ATE Center, with support from AED, developed a survey of all ATE faculty members. This survey was administered via the Internet in October 2000. Of the 34 ATE teaching faculty, 32 completed the survey. An additional 27 of the roughly 100 non-teaching ATE faculty members responded.

3. Site visits – AED researchers visited seven colleges implementing the ATE curriculum during five days in October 2000. At each college, they observed ATE classes, conducted informal focus groups with faculty members, interviewed administrators, and conversed with ATE students.

4. Faculty-reported ATE student data – For each semester between fall 1998 and summer 2002, ATE faculty members submitted to the SC ATE Center, via MS Excel

spreadsheets, basic demographic and course achievement data for each of their ATE students. AED compiled and analyzed these data to track ATE student progress.

5. State System Database – Under the supervision of AED, analysts at JBL Associates in Bethesda, Maryland analyzed the performance outcomes and demographic characteristics of engineering technology associate degree students in the State Tech system between 1992 and 1999. These analyses form the basis of the historical baselines used in this report.

6. Faculty Interviews – In November 1999, AED researchers and graduate assistants conducted 60-minute interviews with 17 of the roughly 20 faculty who taught the ATE curriculum during fall semester 1999. These interviews were transcribed and organized according to topic for analysis.

7. Literature Review – AED researchers, with help from graduate assistants, reviewed over 50 articles and reports pertaining to engineering education and South Carolina industry, in addition to reviewing ATE program and curriculum materials.

8. Cost-Benefit Analysis – In fall 2001, AED researcher David Güemes-Castorena prepared a proposal methodology for undertaking a Cost-Benefit Analysis of the ATE program at Piedmont Technical College. See Appendix C – Cost-Benefit Analysis Proposal, September 28, 2001. The analysis was not performed because the necessary data could not be collected.

Appendix B – Core 181 Student Data

GENDER:	**ETHNICITY:**
0: Male	**1: African American**
1: Female	**2: Asian**
	3: Hispanic
	4: Native American
	5: White
	6: Other / Unspecified
	Blank space: unknown ethnicity

	Number of courses taken					
STUDENTS	***Core 181***	***Core 182***	***Core 183***	***GENDER***	***ETHNICITY***	***COLLEGE***
Student 1	4	4	4	0	5	Tri-County Technical College
Student 2	4	4	4	0	5	Tri-County Technical College
Student 3	4	4	4	0	5	Tri-County Technical College
Student 4	4	4	4	0	1	Tri-County Technical College
Student 5	4	4	4	0	5	Piedmont Technical College
Student 6	4	4	4	0	5	Florence-Darlington
Student 7	4	4	4	0	1	Piedmont Technical College
Student 8	4	4	4	0	1	Piedmont Technical College
Student 9	4	4	4	0	0	Florence-Darlington
Student 10	4	4	4	0	5	Florence-Darlington
Student 11	4	4	4	0	5	Florence-Darlington
Student 12	4	4	4	0	0	Florence-Darlington
Student 13	4	4	4	0	0	Florence-Darlington
Student 14	4	4	4	0	5	Florence-Darlington
Student 15	4	4	4	0	5	Piedmont Technical College
Student 16	4	4	4	0	5	Piedmont Technical College
Student 17	4	4	4	0	5	Piedmont Technical College
Student 18	4	4	4	0	0	Florence-Darlington
Student 19	4	4	4	0	5	Florence-Darlington
Student 20	4	4	4	0	0	Florence-Darlington
Student 21	4	4	4	0	0	Florence-Darlington
Student 22	4	4	4	0	0	Florence-Darlington
Student 23	4	4	4	0	1	Piedmont Technical College
Student 24	4	4	4	0	5	Piedmont Technical College
Student 25	4	4	4	0	1	Florence-Darlington
Student 26	4	4	4	0	0	Florence-Darlington
Student 27	4	4	4	0	0	Florence-Darlington
Student 28	4	4	4	0	0	Florence-Darlington
Student 29	4	4	4	1	1	Piedmont Technical College
Student 30	4	4	4	0	0	Florence-Darlington
Student 31	4	4	4	0	1	Piedmont Technical College
Student 32	4	4	4	0	0	Florence-Darlington
Student 33	4	4	4	0	5	Piedmont Technical College
Student 34	4	4	4	0	5	Florence-Darlington

	Number of courses taken					
STUDENTS	***Core 181***	***Core 182***	***Core 183***	***GENDER***	***ETHNICITY***	***COLLEGE***
Student 35	4	4	4	0	5	Piedmont Technical College
Student 36	4	4	4	0	0	Florence-Darlington
Student 37	4	4	4	0	5	Florence-Darlington
Student 38	4	4	4	0	0	Florence-Darlington
Student 39	4	4	4	0	5	Tri-County Technical College
Student 40	2	4	3	5		Tri-County Technical College
Student 41	2	4	3	5		Tri-County Technical College
Student 42	3	4	3	5		Piedmont Technical College
Student 43	3	4	3	5		Piedmont Technical College
Student 44	3	3	3	1		Piedmont Technical College
Student 45	3	3	3	1		Piedmont Technical College
Student 46	4	3	3	5		Piedmont Technical College
Student 47	4	3	3	5		Piedmont Technical College
Student 48	3	4		1	1	Piedmont Technical College
Student 49	4	2		0	5	Piedmont Technical College
Student 50	4	4		1	6	Tri-County Technical College
Student 51	4	4		0	5	Tri-County Technical College
Student 52	4	4		0	1	Florence-Darlington
Student 53	4	4		0	5	Tri-County Technical College
Student 54	4	4		0	5	Piedmont Technical College
Student 55	4	4		0	5	Tri-County Technical College
Student 56	4	4		0	5	Tri-County Technical College
Student 57	4	4		0	1	Florence-Darlington
Student 58	4	4		0	5	Florence-Darlington
Student 59	4	4		0	5	Tri-County Technical College
Student 60	4	4		0	1	Tri-County Technical College
Student 61	4	4		0	0	Florence-Darlington
Student 62	4	4		0	5	Florence-Darlington
Student 63	4	4		0	1	Florence-Darlington
Student 64	4	4		0	5	Tri-County Technical College
Student 65	4	4		1	5	Tri-County Technical College
Student 66	4	4		0	5	Tri-County Technical College
Student 67	4	4		0	5	Tri-County Technical College
Student 68	4	4		0	5	Florence-Darlington
Student 69	4	4		0	5	Tri-County Technical College
Student 70	4	4		0	1	Piedmont Technical College
Student 71	4	4		0	5	Tri-County Technical College
Student 72	4	4		0	5	Piedmont Technical College
Student 73	4	4		0	5	Tri-County Technical College
Student 74	4	4		0	1	Tri-County Technical College
Student 75	4	4		0	5	Tri-County Technical College
Student 76	4	4		0	5	Tri-County Technical College
Student 77	4	4		1	5	Florence-Darlington
Student 78	4	4		0	5	Tri-County Technical College
Student 79	4	4		0	5	Tri-County Technical College
Student 80	2	4		0	5	Tri-County Technical College
Student 81	2	4		0	5	Tri-County Technical College

	Number of courses taken					
STUDENTS	***Core 181***	***Core 182***	***Core 183***	***GENDER***	***ETHNICITY***	***COLLEGE***
Student 82	2	4		1	5	Tri-County Technical College
Student 83	2	4		0	5	Tri-County Technical College
Student 84	2	4		1	5	Tri-County Technical College
Student 85	2	4		0	5	Tri-County Technical College
Student 86	2	4		0	1	Tri-County Technical College
Student 87	2	4		0	5	Tri-County Technical College
Student 88	2	4		0	5	Tri-County Technical College
Student 89	2	4		0	5	Tri-County Technical College
Student 90	2	4		0	5	Tri-County Technical College
Student 91	2	4		0	5	Tri-County Technical College
Student 92	2	4		1	5	Tri-County Technical College
Student 93	4			1	5	Florence-Darlington
Student 94	4			0	5	Tri-County Technical College
Student 95	4			0	0	Florence-Darlington
Student 96	4			1	5	Tri-County Technical College
Student 97	4			0	1	Piedmont Technical College
Student 98	4			0	5	Tri-County Technical College
Student 99	4			0	1	Piedmont Technical College
Student 100	4			0	5	Florence-Darlington
Student 101	4			0	5	Florence-Darlington
Student 102	4			0	5	Tri-County Technical College
Student 103	4			0	5	Piedmont Technical College
Student 104	4			0	5	Piedmont Technical College
Student 105	4			0	5	Piedmont Technical College
Student 106	4			0	1	Piedmont Technical College
Student 107	4			0	5	Florence-Darlington
Student 108	4			0	5	Piedmont Technical College
Student 109	4			0	5	Tri-County Technical College
Student 110	4			1	5	Florence-Darlington
Student 111	4			0	5	Tri-County Technical College
Student 112	4			0	1	Florence-Darlington
Student 113	4			0	1	Florence-Darlington
Student 114	4			0	5	Florence-Darlington
Student 115	4			0	5	Florence-Darlington
Student 116	4			0	5	Tri-County Technical College
Student 117	4			0	5	Tri-County Technical College
Student 118	4			1	5	Tri-County Technical College
Student 119	4			0	5	Piedmont Technical College
Student 120	4			0	5	Florence-Darlington
Student 121	4			0	5	Tri-County Technical College
Student 122	4			0	1	Florence-Darlington
Student 123	4			0	1	Florence-Darlington
Student 124	4			1	5	Florence-Darlington
Student 125	4			0	0	Florence-Darlington
Student 126	4			0	5	Florence-Darlington
Student 127	4			0	5	Florence-Darlington
Student 128	4			0	5	Tri-County Technical College

	Number of courses taken					
STUDENTS	***Core 181***	***Core 182***	***Core 183***	***GENDER***	***ETHNICITY***	***COLLEGE***
Student 129	4			0	5	Tri-County Technical College
Student 130	4			0	1	Piedmont Technical College
Student 131	4			0	5	Florence-Darlington
Student 132	4			1	5	Tri-County Technical College
Student 133	4			0	5	Florence-Darlington
Student 134	4			1	5	Tri-County Technical College
Student 135	4			0	5	Tri-County Technical College
Student 136	4			0	1	Piedmont Technical College
Student 137	4			0	0	Florence-Darlington
Student 138	4			1	5	Tri-County Technical College
Student 139	4			0	5	Florence-Darlington
Student 140	4			0	5	Florence-Darlington
Student 141	4			1	1	Piedmont Technical College
Student 142	4			0	1	Tri-County Technical College
Student 143	3			0	5	Piedmont Technical College
Student 144	3			0	5	Piedmont Technical College

TOTAL NUMBER OF STUDENTS	144	92	47

Appendix C – Cost-Benefit Analysis Proposal

Piedmont Technical College

Cost-Benefit Analysis Proposal

David Güemes-Castorena, D.Sc.
Paul Bucci, Ph.D.

Academy for Educational Development

Washington, DC

September 28, 2001

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Introduction

The South Carolina Advanced Technological Education (SC ATE) program improvements in engineering technology education have been in place for several academic years at Piedmont College. At this point, the administrators of the program are interested measuring the benefits of the ATE program and demonstrating them to the stakeholders. In this research proposal, AED would, by means of a Data Envelopment Analysis (DEA), compare the costs and benefits of the ATE program with similar programs at Piedmont Technical College, as one measure of the strengths and weaknesses.

Purpose

The purpose of this proposal is to present how a data envelopment analysis could help answer many questions related to the performance and costs of the ATE program compared to other similar programs at the same college.

Background

After several years of the implementation of the South Carolina ATE program, the college's leadership is interesting in evaluating the impact of the ATE program improvements on Institutional Goals. As stated on the Institutional Goals & Operational Plan for 2000-2001, the goals are[26]:

Goal I: Prepare a highly trained and competent workforce

Goal II: Demonstrate accountability for achieving the college mission

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[26] From http://www.piedmont.tec.sc.us/ie/institutional_goals_operational_plan.htm, as of 9/25/01

Goal III: Provide relevant, quality programs and services

Goal IV: Expand access to educational opportunity and training through the use of technology

Goal V: Acquire the financial resources necessary to achieve the college mission

A cost-benefit analysis could help to determine quantitatively how efficiently the Engineering Technology (ET) program - with innovations and incorporation of the SC ATE ET Core curriculum for first year students - has performed, compared to the previous ET program. Further, the cost-benefit analysis could evaluate quantitatively the relative strengths and weaknesses of the new program.

Problem Statement

The proposed cost-benefit analysis could answer the following question:
Is the SC ATE-enhanced program more efficient, compared to the traditional program?

Significance

The significance of the analysis is based not only on the costs of the SC ATE- enhanced program, but on the efficient use of all the program resources. The results of the analysis would show what resources are being underused, or overused, by the Engineering Technology program compared to other programs.

Methodology

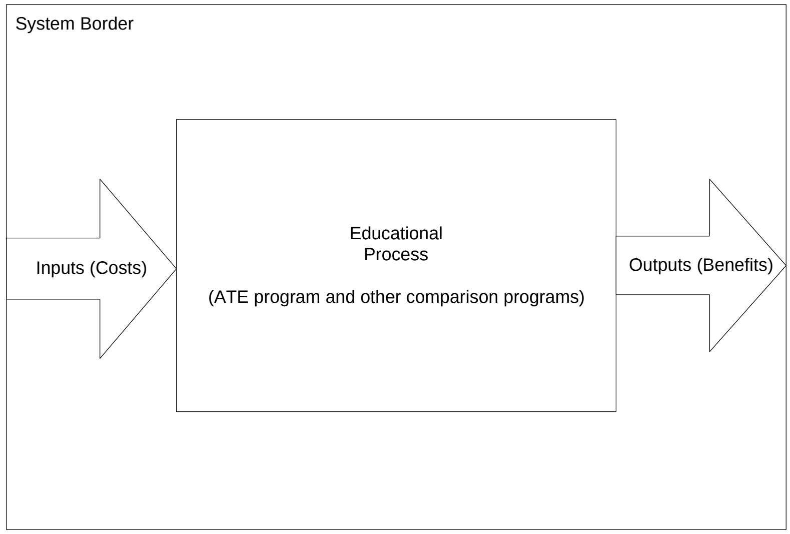
To undertake a cost-benefit analysis, researchers analyze the relationship or function of cost variables and benefit variables. The costs are easier to attain than the benefits; in evaluating educational “benefits” there are many factors that can complicate the analysis:

- The college or organization has multiple goals (e.g. increase persistence) and multiple outputs (e.g. enrollments) and outcomes (e.g. graduates).
- Many of these outputs (e.g. higher order thinking skills) cannot be easily measured or quantified.
- There is a limited knowledge of the relationship between various program inputs (e.g. FTE faculty) and various program outputs (e.g. student enrollment and persistence).

The challenge of explaining the relationships among the inputs and the outputs of the educational process can be addressed by applying a systems perspective to the educational system. From the systems perspective, the cost variables are related to the inputs of the system, and the benefit variables are related to the outputs of the system. Actually, we need not worry about the process by itself, i.e. how the inputs are transformed into outputs.

This analytic approach requires a definition of the system to be studied. That system should contain parameters or boundaries that define the scope of the analysis. Figure 1, Concept of an Educational system, identifies the system of analysis.

Figure 1. Concept of an Educational System.



In this case, the system can be the Engineering Technology program, and it can be compared versus other programs in the school. The system can be analyzed at different levels: cohort, program, college, and so on. The recommended level for this study is the cohort, since it is possible to collect data for different cohorts, and the study can be followed through the time.

The input and the output variables should be carefully defined and measured. Since this study, as many others, would attempt to measure past and present performance, and it is limited by cost-time-labor-variables, it likely will use data/information already collected or at hand, data that are easy to collect.

Selection of the method

As mentioned before, the cost-benefit analysis can be translated into an "input/output" analysis where the objective is to minimize the value of the ratio. A minimization problem can be easily converted into a maximization problem, in which case the problem would now be an "output/input" analysis. This type of analysis is also known as an efficiency measurement analysis, and can help us to determine what the efficiency of each of the programs is.

Cost-benefit analysis usually entails either a ratio analysis, a regression analysis, or a data envelopment analysis. The ratio analysis relates a single output to single input (e.g. student faculty ratio). Regression analysis determines cause-effect relationships; data envelopment analysis (DEA) is a method of analysis that can deal with multiple inputs and outputs simultaneously. Whereas ratio analysis can not deal with multiple outputs, DEA deals with multiple inputs and outputs. Regression analysis requires a specification of the educational process or production function, whereas DEA does not need it; nor is this specification critical for a cost-benefit analysis for the number of one-to-one or one-to-many relationships between educational inputs and outputs is limited.

Since we are assuming that the analysis will include multiple inputs-multiple outputs, and that the relationship among the inputs and the outputs is not well understood, data envelopment analysis is therefore the best analytic tool to use.

Data Envelopment Analysis Method

DEA is a linear programming-based technique for measuring the relative performance of the programs, where the presence of multiple inputs and outputs makes it difficult to determine which program is most efficient. DEA can be extrapolated from an inputs/outputs analysis, to provide a costs-benefits analysis (for more information on DEA, see Appendix C-1).

DEA is used to estimate the efficiencies of similar educational programs. Efficiency can be defined as "the ratio of the effective or useful output to the total input in a system" according to the American Heritage College Dictionary (1997). In the simplest case where a decision making unit (DMU) has a single input and a single output, efficiency is defined as:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}.$$

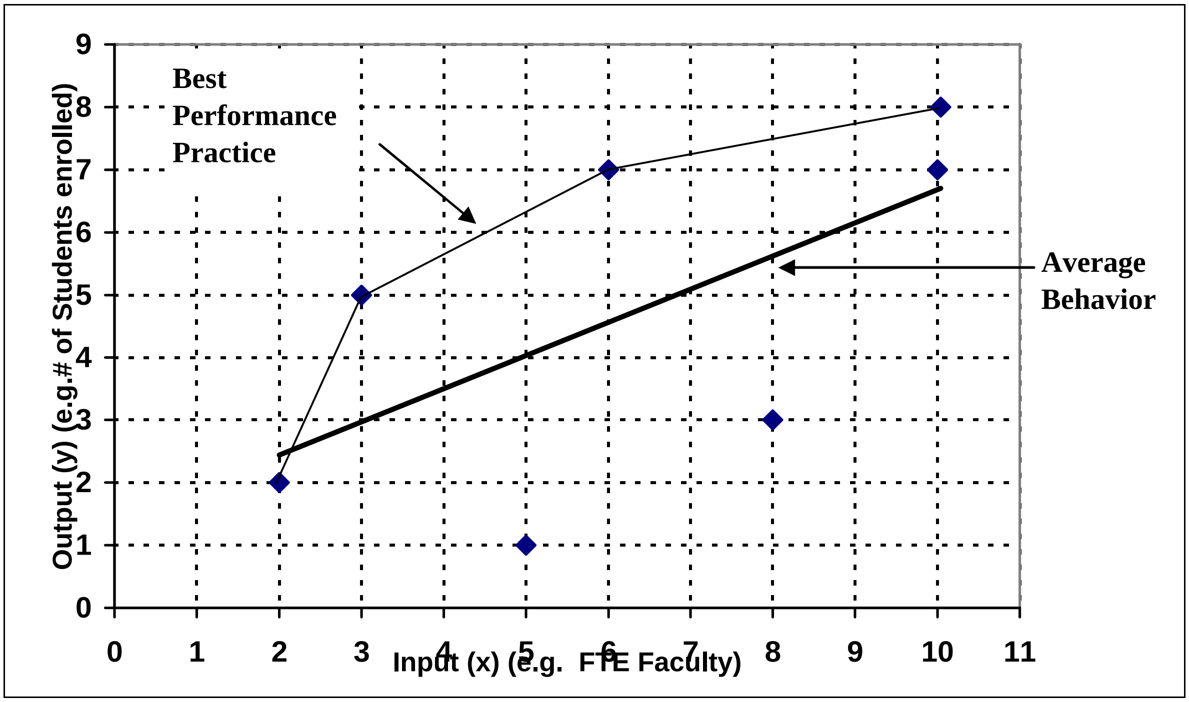
In the case of multiple outputs and multiple inputs, efficiency can be defined as:

$$\text{Efficiency} = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}.$$

For a single input – single output case for several programs, a graphical representation of the data envelopment analysis would look similar to the one shown in Figure 2. A graphical representation for a multiple inputs-outputs requires more than two dimensions.

Multiple outputs/inputs analysis can be solved using linear programming techniques; and the result is a set of best-performing programs that use their resources more efficiently. Additionally the DEA multiple outputs/inputs analysis identifies peer comparison programs and performance gaps for relatively inefficient programs.

Figure 2. Graphical representation of a DEA analysis for one input and one output.



Multiple outputs/inputs analysis requires for benchmarking purposes a set of peer or comparison programs that have similar objectives, inputs and outputs. This permits comparison of the ATE programs with other comparable technology programs. The cohort might be the best unit for analysis, since the entire program as a unit might be too big and the individual student too small a unit for analysis. Also, for purposes of comparison, DEA requires that the number of the units to be used in the analysis to be three times more than the number of input variables times the number of output variables. For example, if 4 input variables and 5 output variables are to be used in the analysis, we would need 60 cohorts in order to conduct the study. If the ATE has 12 cohorts already, the other 48 cohorts might have to be drawn from both historical and current data.

Variables to be used

The variables to be used are selected based on meaningfulness to the study and availability of the data. Data would be collected and analyzed for each cohort.

Some of the input variables recommended for this study are:

- Number of Full-time Equivalent (FTE) faculty teaching ATE
- Total ATE course-load
- FTE/FT staff
- Faculty cost (Salaries and benefits) and/or ATE program cost
- Entering ASSET scores
- Students/scholars marketing and recruiting cost

Some of the output variables recommended for this study are:

- FTE students enrolled at program (total and minority)
- FTE students enrolled at completion of first program year (total and minority)
- Degrees awarded
- Scholarships (# students, and total $)
- Graduates who had maximum Pell Awards
- Average GPA
- Time to completion (number of semesters)
- Students who had to work/financial aid

An input variable is a resource to the system, and the fewer the better. An output is a desirable outcome for the system; and therefore, the more, the better.

The suggested variables are easily measurable and some of the ratios obtained are commonly used:

$$\text{Average Cost per Student} = \frac{\text{Program Cost}}{\text{FTE Students}}$$

$$\text{Student - Faculty Ratio} = \frac{\text{FTE Students}}{\text{FTE Faculty}}$$

$$\text{Scholarship Ratio} = \frac{\text{Total Scholarship \$}}{\text{Total Program \$}}$$

Graduation Rate

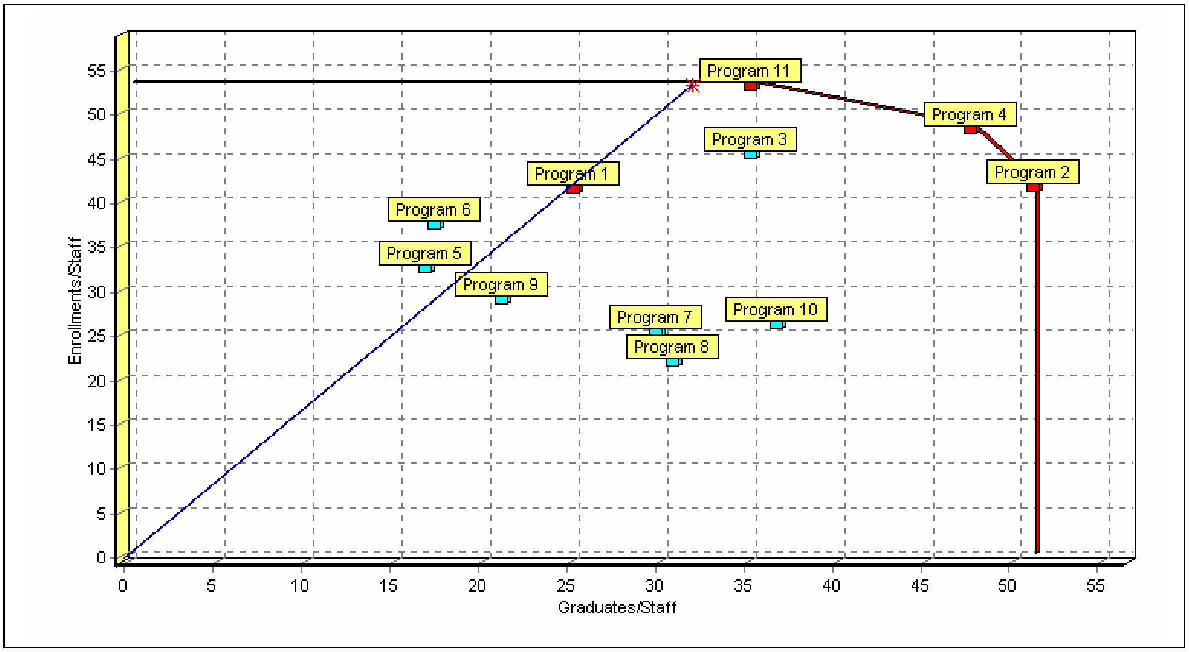
Many of these variables are used by the SC Commission on Higher Education as well as other national and international educational organizations.

Expected Results

The results of the analysis would appear as an efficiency coefficient for each cohort where a 100% means the most efficient and 0% means the least efficient in the use of the resources.

A graphical representation of the results is possible for a one-input and two-output variables analysis. For example, Figure 3 shows a data envelopment analysis of 11 programs, and it compares the number of staff, enrollments and graduates for each program.

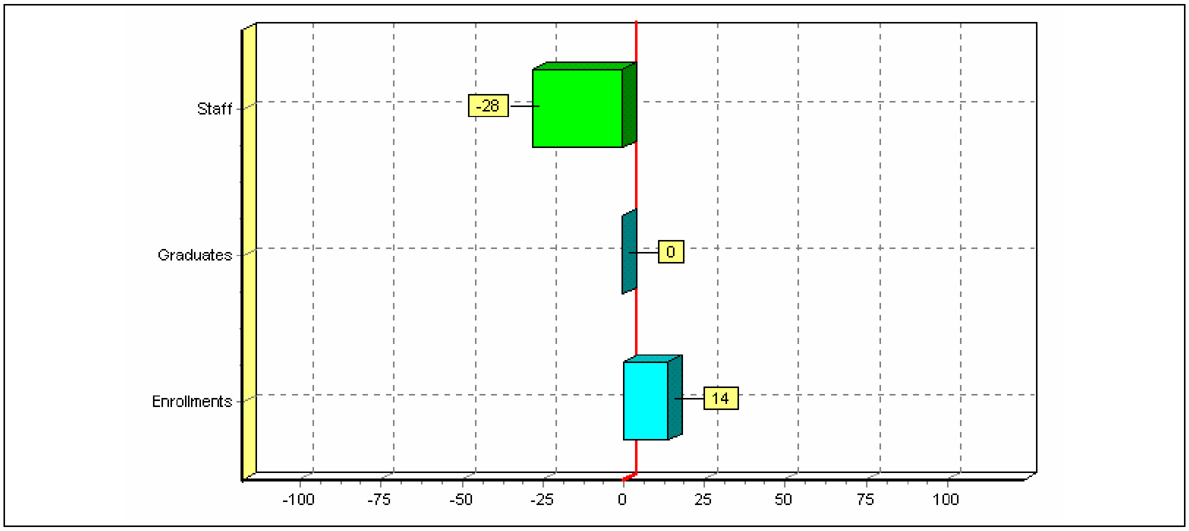
Figure 3. Example of results from a data envelopment analysis.



The programs number 2, 4 and 11 are the most efficient in the use of the staff to enroll more students and produce more graduates. Program 1, for example, can take Program 11 as example for improvement.

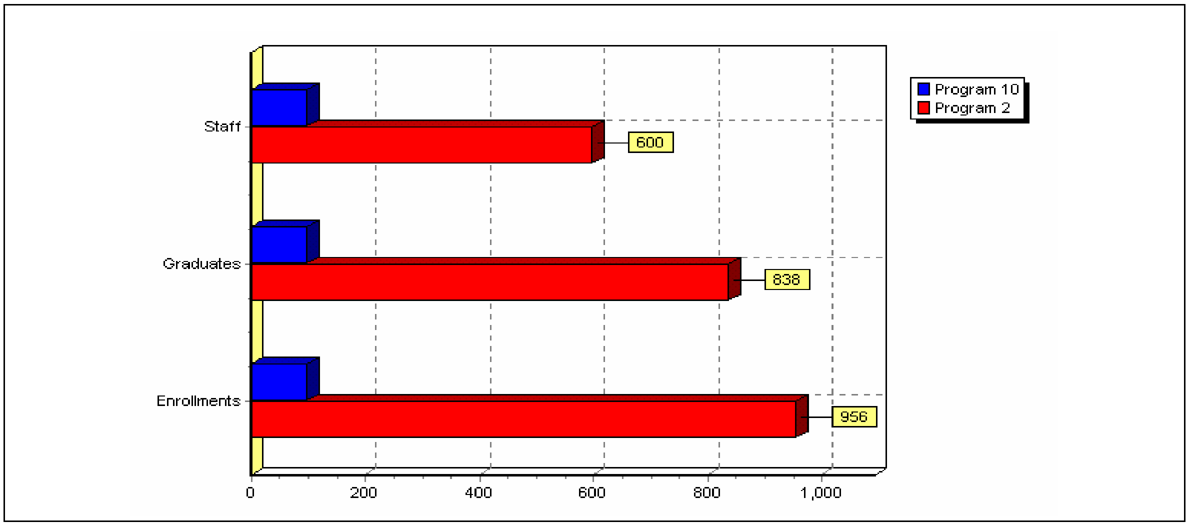
Figure 4 shows that Program 1 would need to reduce staff by 28 and increase the number of graduates by 14 if 100% efficiency were to be reached. In this case, Program 11 is setting the standard for Program 1.

Figure 4. DEA analysis for improvement.



The benchmarking that can be performed based on the DEA analysis is shown in Figure 5, where the inputs and the outputs of the Programs 2 and 10 are compared. In this case, program 2 is using the given resources much more efficiently than program 10. In this way, by identifying the best-performing program and its top-performing standards, DEA can compare the relative efficiency of various similar programs.

Figure 5. DEA analysis for improvement.



Relevant DEA Bibliography

Arnade, Carlos A., and United States. Dept. of Agriculture. Economic Research Service. Using data envelopment analysis to measure international agricultural efficiency and productivity. Technical bulletin (United States. Dept. of Agriculture) ; no. 1831. [Washington, D.C.]: U.S. Dept. of Agriculture Economic Research Service, 1994.

Bates, J.M. "Measuring predetermined socioeconomic 'inputs' when assessing the efficiency oe educational outputs." Applied Economics 29.1 (1997): 85-93.

Boussofiane, A., R. G. Dyson, and E. Thanassoulis. "Applied data envelopment analysis." European Journal of Operational Research 51.1 (1991): 1-15.

Charnes, A. Data envelopment analysis : theory, methodology, and application. Boston: Kluwer Academic Publishers, 1994.

Charnes, A., and W. W. Cooper. "Preface to topics in Data Envelopment Analysis." Annals of Operations Research 2 (1985): 59-94.

Charnes, A., Arie Y. Lewin, and L. M. Seiford. From efficiency calculations to a new approach for organizing and analyzing : DEA fifteen years later. Annals of operations research ; v. 73. Bussum, the Netherlands: Baltzer Science, 1997.

Chu, Xuehao, et al. Measuring transit performance using data envelopment analysis. Uci-Its-Wp, 90-1. Irvine, CA: Institute of Transportation Studies University of California Irvine, 1990.

Cooper, William W., Russell G. Thompson, and Robert McDowell Thrall. Extensions and new developments in data envelopment analysis. Annals of operations research ; v. 66. Amsterdam: Baltzer Science, 1996.

Farrell, F.M. “The Measurement of Productive Efficiency.” Journal of the Royal Statistical Society 120 (1957): 253-290.

Hensher, David A., W. G. Waters, and University of Sydney. Institute of Transport Studies. Using total factor productivity and data envelopment analysis for performance comparisons among government enterprises : concepts and issues. Working paper / University of Sydney. Institute of Transport Studies ; no. ITS-WP-93-10. [Sydney]: University of Sydney Graduate School of Business Institute of Transport Studies, 1993.

Jacobs, Rowena, and University of York. Centre for Health Economics. Alternative methods to examine hospital efficiency : data envelopment analysis and stochastic frontier analysis. [York, England: University of York Centre for Health Economics, 2000.

Klimberg, Ronald, and Don Kern. Understanding data envelopment analysis (DEA). Boston, MA: Boston University School of Management, 1992.

Klimberg, Ronald, and Michael Puddicombe. A multiple objective approach to data envelopment analysis. Boston, MA: Boston University School of Management, 1995.

Levin, Melvin R., and Alan Shank. Educational investment in an urban society: costs, benefits, and public policy. New York,: Teachers College Press, 1970.

Minken, Harald, and Transportøkonomisk institutt (Norway). Effektivitetsmåling med dataomhyllingsanalyse : eksempel fra lastebiltransport. TØI rapport, 258/1994.

Ray, Anandarup, and World Bank. Cost-benefit analysis : issues and methodologies. Baltimore: Published for the World Bank [by] Johns Hopkins University Press, 1984.

Ryan, Robert Lee. A data envelopment analysis of organizational climate and performance in public transit operations.

Salinas Jiménez, Javier, et al. Data envelopment analysis applied to quality in primary health care. [York, England: Centre for Health Economics University of York], 1994.

Sengupta, Jatikumar. Dynamics of data envelopment analysis : theory of systems efficiency. Dordrecht ; Boston: Kluwer Academic Publishers, 1995.

Shroff, Homeé F. E. "Siting efficiencies of long-term health care facilites [sic] : the northern Virginia health system." , 1992.

Woodhall, Maureen, and International Institute for Educational Planning. Cost-benefit analysis in educational planning. Fundamentals of educational planning ; 13. 3rd ed. Paris: Unesco International Institute for Educational Planning, 1992.

Appendix C-1: Data Envelopment Analysis

Data Envelopment Analysis (DEA) is an approach to performance assessment which uses linear programming-based techniques and principles of frontier analysis for measuring the relative performance of decision-making units (DMU[27]) where the presence of multiple inputs and outputs makes the comparison difficult. DEA provides a single measure of performance based on multiple inputs and outputs.

DEA model

DEA is based on the work of Farrell's (1957) paper "The Measurement of Productive Efficiency" (Farrell) and can be considered a generalization of Farrell's single-output/input technical efficiency measure to the multiple-output/input case (Charnes).

DEA is used to estimate the efficiencies of homogeneous DMU. Before proceeding, efficiency can be defined as "the ratio of the effective or useful output to the total input in a system" according to the American Heritage College Dictionary (1997). In the simplest case where a DMU has a single input and a single output, efficiency is defined as:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}.$$

In the case of multiple outputs and multiple inputs, efficiency can be defined as:

$$\text{Efficiency} = \frac{\text{weighted sum of outputs}}{\text{weighted sum of inputs}}.$$

With multiple outputs/inputs DMUs, efficiency is difficult to estimate, especially when the weights are unknown and need to be defined. Charnes, Cooper, and Rhodes (1978) developed a method where each individual DMU has its own set of weights, and its efficiency is relative to the others DMUs.

The DEA model theory proposes that the efficiency of a target unit j_0 can be obtained by solving the following model: (Boussofiane, Dyson and Thanassoulis)

$$\text{Max } h_0 = \frac{\sum_{r=1}^{t} u_r y_{rj_0}}{\sum_{i=1}^{m} v_i x_{ij_0}} \qquad \textbf{Equation 1}$$

Subject to:

$$\frac{\sum_{r=1}^{t} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \quad j = 1,\ldots,n,$$

$$u_r, v_i \geq e, \quad \forall r \text{ and } i,$$

where

y_{rj} = amount of output r from unit j,

x_{ij} = amount of input i from unit j,

u_r = the weight given to output r,

v_i = the weight given to input i,

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[27] DMU is a generic term to describe departments, divisions, or similar units having similar goals, mission, inputs and outputs.

n = the number of units, or DMU

t = the number of outputs,

m = the number of inputs,

e = a small positive number.

Equation 1 means the following: DMU j_0 is efficient ($h_0 = 1$) only when comparisons with other relevant DMU do not provide evidence of inefficiency in the use of any input or output.

The solution to Equation 1 is the efficiency of DMU j_0. The efficiency of DMU j_0 is maximized subject to efficiencies of all units in the set having an upper bound of 1 (or 100%, according to the reader's preferences). As mentioned previously, this model has the key feature of treating the weights u_r and v_i as unknown. Efficiencies for all units are obtained by solving Equation 1 for each unit at the time. The values of the weights will change for each unit being solved, as mentioned earlier.

Efficiency can be redefined, according to Charnes and Cooper (1985), (Charnes and Cooper) based on Equation 1 as:

100% efficiency is attained (for a DMU) when:

1. None of its outputs can be increased without either (i) increasing one or more of its inputs, or (ii) decreasing some of its other outputs;
2. None of its inputs can be decreased without either (i) decreasing some of its outputs, or (ii) increasing some of its other inputs.

The model presented in Equation 1 is a fractional linear program that can be converted into a linear form, in order to use methods of linear programming for its solution. The transformation is presented in Equation 2.

$$\text{Max } h_0 = \sum_{r=1}^{s} u_r \; y_{rj_0}$$ **Equation 2**

Subject to:

$$\sum_{i=1}^{m} v_i x_{ij_0} = 1$$

$$\sum_{r=1}^{t} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \; \forall j$$

$$u_r, v_i \geq e$$

In Equation 2 the objective function has been linearized, since in maximizing a ratio it is the relative magnitudes of the numerator and denominator that are important and not their actual values. That is why in Equation 2 the denominator has been set to 1 (or 100%) arbitrarily, and the numerator is maximized.

DEA graphical representation

A graphical way of representing DEA is useful and illuminating. Figure 6 presents single-input (*x*) - single-output (*y*) DMUs for graphical representation purposes, since a multiple inputs-outputs approach is multidimensional. DEA focuses on the individual DMUs rather than their average behavior. DEA is able to determine the best performers, as well as to determine a set of target inputs and outputs for the inefficient DMUs.

The set of target inputs and outputs for the inefficient DMUs can be obtained from an extrapolation from the efficient frontier. This will be explained by using Figure 7, which shows a multiple output-single input case.

Figure 6. Graphical Example of DEA.

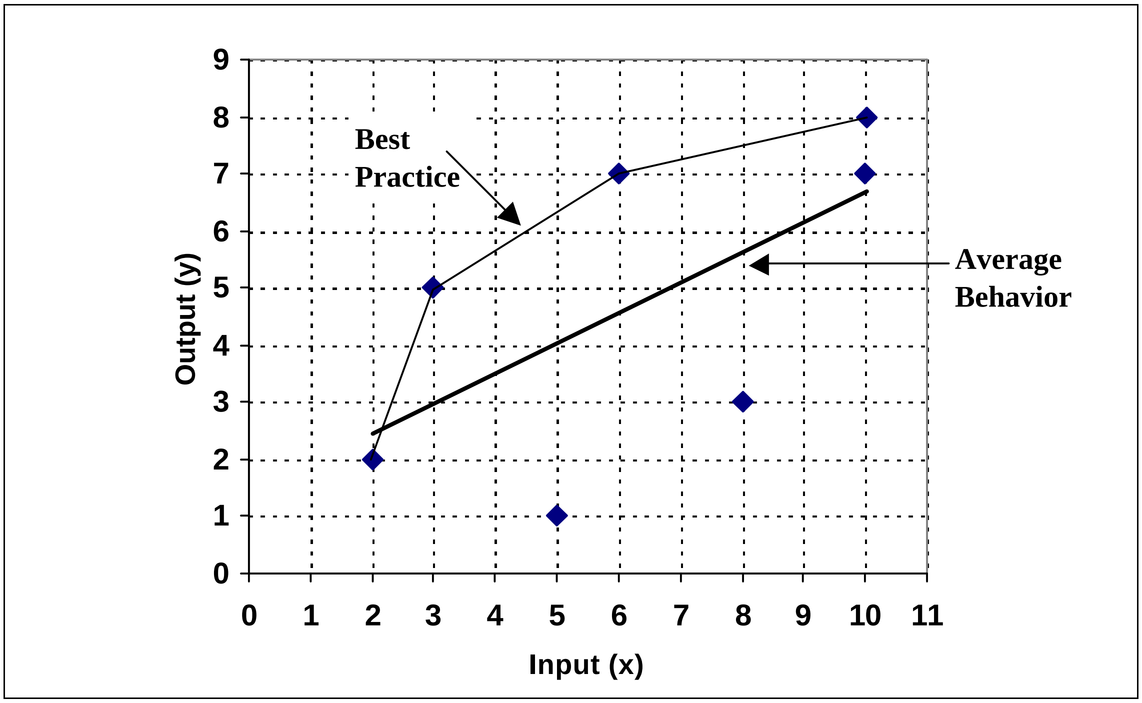
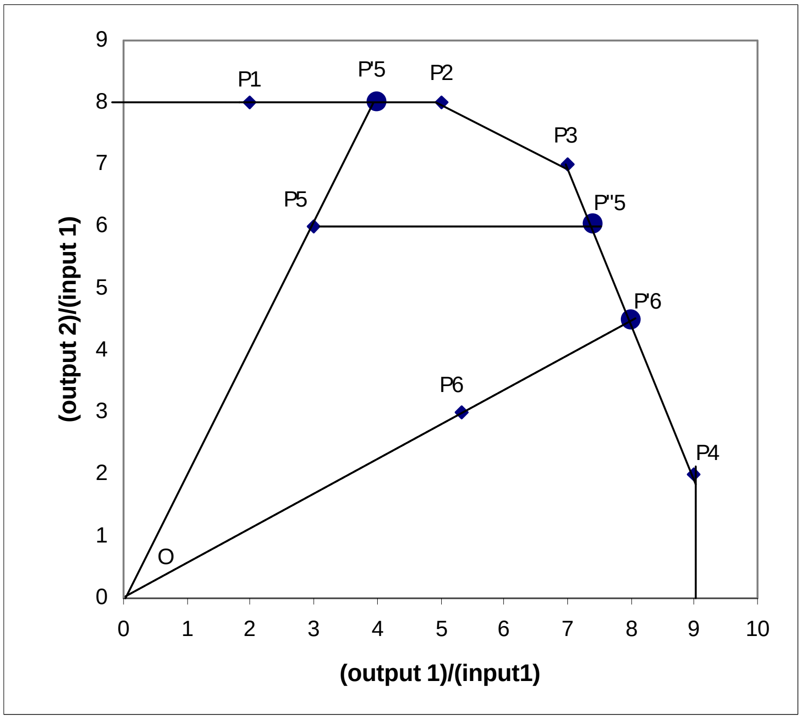


Figure 7 shows a set of DMU {P1, P2, P3, P4, P5, P6}. Each DMU consumes the same amount of “input 1” and produces different amounts of “output 1” and “output 2”. In this specific case, the DMUs that produce greater amounts of outputs are the most efficient, and they form the “efficient data envelope.” In Figure 7, the DMUs that are 100% efficient are P1, P2, P3, and P4. DMUs P5 and P6 are inefficient and they are below the “efficient data envelope.” In this case, the envelope has been extended between the axes and DMU P1, as well as between the axes and DMU P4.

Figure7. Graphical Representation of a Two-Outputs & One-Input DEA.



For the inefficient DMU P5, the peer group consists of the DMU P1 and P2 and a set of targets for P5 is provided at P'5. For P5 there is more than one possible target, such as P''5 if P5 cannot increase the production of output 2, and P''5 would be the result of increasing the production solely of output 1. The same happens with P6, but now the peer group consists of the DMU P3 and P4. As mentioned before, P'6 is a "pro-rated" target for P6, and it is not the only one.

Efficiency for P5 can be calculated using Figure 7. Since P5 can be efficient at P'5, then P5's efficiency is the ratio O P5 / O P'5, where O is the origin point (0,0), O P5 is the distance from the origin to P5, and O P'5 is the distance from the origin to P'5.

DEA model selection

The CCR model is the most widely used and best known implementation of the DEA framework. The CCR model was named after those who developed it Charnes, Cooper, and Rhodes in 1978. Since then, many developments have been made to the "basic" DEA model, providing DEA with a more powerful selection of models capable of being used for many different studies. Table 1 presents the most frequently used DEA models.

Table 1. Comparison of Basic DEA Models (Charnes et al., 1994).

Model	Returns to scale	Envelopment surface
Additive	Variable	Piecewise linear
BCC Input	Variable	Piecewise linear
BCC Output	Variable	Piecewise linear
CCR Input	Piecewise constant	Piecewise linear
CCR Output	Piecewise constant	Piecewise linear
Invariant Multiplicative	Variable (log-linear)	Piecewise Cobb-Douglas
Variant Multiplicative	Constant (log-linear)	Piecewise log-linear

The selection of a specific DEA model is determined by (Charnes et al., 1994; Bates, 1997): (Bates)

1. The implicit returns-to-scale properties.
2. The geometry of the envelope surface. This is important since the efficiency is a function of the envelope surface geometry.
3. Nature of the problem: input minimization or output maximization.

The returns to scale can be constant or variable. The return to scale relates the way the output changes when a change in the inputs occurs. If the inputs are doubled and the process produces double outputs, the process can be modeled with “constant returns to scale.” On the other hand, if the inputs are doubled and the process produces more than/less than the double of outputs, then the process can be modeled with “variable returns to scale.” Since all the universities are autonomous and are free to select their own path to achieve their goals, the variable returns to scale is more likely to reflect the reality than the constant returns to scale.

The geometry of the surface is directly related to the chosen model. In this study, the BBC and CCR models will be the ones considered, due to their simplicity. Both models have a piecewise linear envelope surface.

The selection of input-minimization or output-maximization for this study requires careful consideration. In order to be efficient, a university needs to minimize their inputs or produce more outputs that it already has. Input minimization would imply a reduction of funding, faculty, overhead, and similar inputs to the university. Output maximization would imply an improvement of terminal efficiency and better distribution of the enrollment.

In this study, the selected model was the BCC –output oriented. The BCC model was named after those who developed it –Banker, Charnes, and Cooper– in 1984. The BCC –output oriented model uses the variable returns to scale, output maximization, and is shown in Table 2, where X is the input matrix and Y is the output matrix.

Table 2. BCC DEA Model Selected.

	Output Oriented BCC Primal		Output Oriented BCC Dual
	$\max_{f,l,s^+,s^-} \quad z_0 = f + e \cdot \vec{1}s^+ + \quad e \cdot$		$\min_{m,v,v_0} \quad q_0 = v^T X_0 + \mathrm{v}_0$
s.t.	$fY_0 - Yl + s^+ = 0$	s.t.	$m^T Y_0 = 1$
	$Xl + s^- = X_0$		$-m^T Y + v^T X + v_0 \vec{1} \geq 0$
	$\vec{1}\, l = 1$		$m^T \geq e \cdot \vec{1}$
	$l, s^+, s^- \geq 0$		$v^T \geq e \cdot \vec{1}$
			v_o is free

The output oriented BCC dual model can be represented without vectors in Equation 3.

Equation 3

$$\text{Min } \mathrm{q}_0 = \sum_{r=1}^{m} v_i \; x_{ij_0} + \mathrm{v}_0$$

Subject to:

$$\sum_{r=1}^{t} u_r y_{rj_0} = 1$$

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{t} u_r y_{rj} + \mathrm{v}_j \geq 0, \; \forall j$$

$$u_r, v_i \geq e$$

v_j = free