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Success Strategies for First-Year Pre-Engineering Students

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Abstract

An innovative, comprehensive program for entering engineering and science students called CircLES (Circles of Learning for Entering Students) has been implemented at the University of Texas at El Paso (UTEP) to improve student success and retention in the first year and to increase persistence to graduation. An important part of this program addresses the needs of students who enter the university with a weak math background that requires them to complete one or more developmental math courses. These students, who typically completed only the minimum math requirements in high school, are placed into non-credit courses that build their math background to college-level.

The CircLES program enrolls groups of twenty-five students into four courses: developmental math, English composition, university seminar (required of all entering freshmen), and introduction to engineering. "Clustering" of students in these four courses creates a learning community that would otherwise not develop at UTEP because it is a commuter university. Interaction between the four instructors, especially between the math, university seminar, and introduction to engineering instructors, creates an interdisciplinary team whose goal is to promote student success. Student success strategies, self-responsibility, and critical thinking skills are developed in the university seminar course. The developmental math course provides the math background necessary for these students to enter college-level math courses. Most of the students have little difficulty in passing the developmental math course, but they have very poor understanding of how to use the abstract concepts learned in math to solve problems. This weakness causes many students to do poorly in subsequent technical courses and/or to give up on a career in engineering. The introduction to engineering course serves as a bridge between the abstract concepts learned in math and their application to "real" problems and explores the world of engineering through hands-on projects. The problem solving skills learned in this course provide a solid foundation for success in the math, science and engineering courses that follow.

This paper describes the evolution of the "cluster" learning community, the importance of the "cluster" instructor team, the development of student success strategies and critical thinking skills, the enhancement of applied math skills through problem solving, the use of hands-on projects to explore engineering and further develop applied math skills, and the development of team skills that support student learning.

Background

The University of Texas at El Paso (UTEP) is a comprehensive, public, urban institution. As a mid-size, commuter campus located in the world's largest binational metropolitan center, the University of Texas at El Paso is recognized as one of the nation's most successful educators of Hispanic students. Over 69 percent of its approximately 15,000 students are Hispanic and an estimated two-thirds of them are the first in their families to attend college. More than 82 percent of students are from the local region and normally live at home.

In the last two decades, UTEP has developed and sustained major institutional change initiatives and curricular reform to meet the needs of the region's students. The driving force has been and continues to be the development of institutional structures and processes that increase the involvement of students who are less-affluent, work outside the university, have substantial family obligations, and/or are less prepared for college than students who attend small private residential colleges. UTEP is committed to recruiting and educating the region's students and helping them compete successfully on a global scale. As a consequence, it has become the only major urban university in the Southwest whose student body matches the demographics of the region it serves.

Each fall semester there are about 330 first-time freshman who declare engineering as their major. Only about 10 percent of these students place into *Calculus I*, and therefore, are qualified to begin the standard engineering programs. Approximately 90 percent of first-time engineering freshmen are diverted into pre-engineering where they can develop their math background to college-level and improve their learning and study skills so that they can be successful in engineering. About 60 percent of first-time engineering freshmen place into developmental math courses that are essentially a repeat of high school algebra. Approximately 30 percent place into *Pre-calculus*.

Entering engineering students at UTEP are probably very similar in their background to entering students at other comprehensive, public, urban universities. The generic profile of an entering engineering student at UTEP includes the characteristics listed below. In general, entering

- First in family to attend college
- Weak math background
- Underdeveloped communication skills
- Poor learning skills
- Poor time management skills
- Underdeveloped critical thinking skills
- Unfocused career and life goals
- Minimal time spent on campus
- Don't develop support groups
- Low self-confidence
- Poor social skills
- Poor use of university resources

students do not perceive themselves as having most of these deficiencies. They have to be carefully led to the realization that they need help to prepare themselves to succeed at the university. The CircLES program was created to address entering student deficiencies and to attempt to simulate a residential campus environment by building learning communities among the students.

UTEP’s Evolving CircLES Program

Based on its record of dedication to and success in serving historically under-represented populations, the National Science Foundation awarded the University of Texas at El Paso a Model Institutions for Excellence (MIE) grant. The MIE initiative is a groundbreaking program that supports colleges and universities in their efforts to become models for improving the quantity and quality of science, engineering, and mathematics (SEM) graduates.

A major element in UTEP’s design and implementation of its model has involved the development and establishment of an entering students program in science and engineering known as CircLES (Circles of Learning for Entering Students). The program is designed to meet the specific curricular and social needs of entering pre-engineering and pre-science students. In the past these students had no department, program of study, or departmental advisor. The program is, in a sense, an "academic home" for pre-science and pre-engineering students who are not able to matriculate into a program of study. The CircLES program is designed to provide students with an opportunity to:

- Establish close relationships with faculty teaching cluster courses;
- Make new friends who have interests in similar disciplines;
- Develop study groups and a culture of persistence;
- Form a connection to and an identification with the university;
- Learn about and use university resources;
- Participate in academic and social activities that encourage "best effort;"
- Provide feedback for the continuous improvement of the CircLES program.

One of the most important parts of the CircLES program is the “clustering” of small groups of students in three or four courses. Students are enrolled in a “cluster” of courses based on their placement in math and English determined by placement tests administered during a week-long orientation. Each “cluster” consists of a math course, an English course, and a freshman seminar course which is required of all entering students regardless of major. An introductory engineering course is added to some clusters. All first-time engineering students are clustered regardless of their math and English placement. The basic clusters are illustrated in Figure 1 where the D indicates a developmental course that cannot be counted toward any degree. Each basic cluster can have up to three variations depending upon students’ English placement. The three English courses in order from lowest to highest level are *Introduction to Writing* (D), *Basic English Composition* (D), or *Expository English Composition*. Each of the freshman seminar *(Seminar in Critical Inquiry*) sections and the *Introduction to Engineering* sections is taught by engineering faculty. The *Reverse Engineering Lab* is taught by engineers from the staff of the Texas Manufacturing Assistance Center (TMAC) located on the UTEP campus.

Students are clustered each semester until they complete *Pre-calculus*. Figure 2 illustrates the cluster sequencing for a student entering UTEP with placement in *Introductory Algebra* and *Basic English Composition*. An asterisk (*) after a course indicates that it is part of a cluster.

Introductory Algebra Cluster
- *Introductory Algebra* (D)
- *Seminar in Critical Inquiry*
- English

Intermediate Algebra Cluster
- *Intermediate Algebra* (D)
- *Seminar in Critical Inquiry*
- English
- *Introduction to Engineering* (D)

Precalculus Cluster
- *Pre-calculus* (D)
- *Seminar in Critical Inquiry*
- English
- *Reverse Engineering Lab* (D)

Calculus I Cluster
- *Calculus I*
- *Seminar in Critical Inquiry*
- English

Figure 1. Basic cluster structure for UTEPs CircLES program.

First Semester-Entering Student
- *Introductory Algebra**
- *Basic English Composition**
- *Seminar in Critical Inquiry**
- Core Elective

Second Semester
- *Intermediate Algebra**
- *Expository English Composition**
- *Introduction to Engineering**
- Core Elective

Third Semester
- *Pre-calculus**
- *Research & Critical Writing**
- *Reverse Engineering Lab**
- Core Elective

Fourth Semester-Enter Major
- *Calculus I*
- *General Chemistry I*
- *Chemistry Lab*
- Intro to Engr. or Comp. Science

Figure 2. Cluster sequencing for a student beginning with *Introductory Algebra*.

The cluster courses incorporate cooperative learning as a pedagogical strategy for increasing student learning and success in the courses. Faculty in each of the cluster courses implement cooperative elements and team building based on the needs of the students, the structure of the subject matter and activities, and the knowledge of the instructor. Cross-discipline cooperation between the instructors in a cluster is strongly encouraged. Peer facilitators (undergraduate teaching assistants) are present in the classrooms of the cluster sections and assist the instructor with team activities. They also serve as mentors and tutors for students in their cluster, both in and out of the classroom.

Although each of the basic clusters is important to the success of entering engineering students, our experience indicates that the Intermediate Algebra Cluster is critical to the success of pre-engineering students, and therefore, this paper will focus on that cluster.

Intermediate Algebra Cluster

The basic Intermediate Algebra Cluster consists of four courses - *Intermediate Algebra*, *Seminar in Critical Inquiry*, *Introduction to Engineering*, and *Basic English Composition* or *Expository English Composition* (depending on students' English placement). *Intermediate Algebra*, *Introduction to Engineering*, and *Basic English Composition* are developmental courses that cannot be counted toward any degree.

Intermediate Algebra is essentially high school algebra II with some college algebra. The topics covered are polynomials, rational expressions and equations, radical expressions, rational exponents, complex numbers, quadratic equations, line graphing, and geometry. Most students have little difficulty passing this course, but they have a very poor understanding of how to apply the abstract concepts they learn in the course to solving practical problems.

Basic English Composition is a developmental course that prepares students for the first required English course, *Expository English Composition*. The course is an introduction to the writing process: pre-writing, drafting, revision, and editing/proofreading. Editing skills (punctuation, spelling, word usage, grammar) are presented in the context of the student's own writing.

Expository English Composition is the first of two English courses required of all students. This course addresses academic writing tasks through five well-developed essays: informative, evaluative, cause and effect, persuasive, and positional. The course also emphasizes critical reading and critical thinking.

Introduction to Engineering is a developmental course specifically designed to fit in the Intermediate Algebra Cluster and cannot be counted as credit toward an engineering degree. The course targets a math level of high school algebra II. The primary goals of the course are to serve as a bridge between the abstract concepts learned in math and their application to practical, "real world" problems, to provide extensive practice in setting up and solving a wide variety of applied problems, and to explore careers in engineering and computer science.

The connections among the four cluster courses are illustrated in Figure 3. Clearly, the primary connection is between *Seminar in Critical Inquiry* and *Introduction to Engineering*. Students are introduced to critical thinking, learning skills, study skills, team skills, and self-responsibility in the seminar course. These topics are then reinforced in *Introduction to Engineering*. Both the *Introduction to Engineering* and seminar courses interact with the English composition course through critical thinking, electronic and library research, and writing. The *Introduction to Engineering* course connects with the *Intermediate Algebra* course via critical thinking, problem solving, and math applications. There is almost no interaction between the seminar and English composition courses and the *Intermediate Algebra* course.

The faculty teaching the cluster courses ideally form a teaching team that interacts on a regular basis throughout the semester. Communication among the faculty occurs through phone calls,

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   English         1,6,7      University                  Intermediate
Composition  -------------  Seminar  ----------------  Algebra
          \                        |                         /
           \                       |                        /
            \          1,2,3,4  |  5,6,7,8                /
             \                     |                      /
     1,6,7  \                      |                    /  1,9,10
               \                   |                   /
                \                  |                  /
                 \                 |                 /
                  \ _ Introduction to __/
                        Engineering
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1 - Critical Thinking	6 - Electronic & Library Research
2 - Learning Skills	7 - Written Communication
3 - Study Skills	8 - Oral Communication
4 - Team Skills	9 - Problem Solving
5 - Self-responsibility	10 - Math Applications

Figure 3. Connections between courses in the Intermediate Algebra Cluster.

e-mail exchanges, and scheduled meetings. Some of the results from this regular interaction include:

- Evolution of a cross-discipline faculty community,
- Focus on the common goal of increasing the probability of success for entering students,
- Development of linked projects and/or assignments,
- Comparison of students' progress in each cluster course to identify students who are having difficulty in one or more courses, and
- Multiple interventions for at-risk students.

Seminar in Critical Inquiry

During 2000, all components of the University of Texas System, including UTEP, adopted a new core curriculum. The UTEP core includes *Seminar in Critical Inquiry* as an institutionally designated option. It is often referred to within the UTEP community as just University Seminar. All students entering UTEP, who have undertaken less than 30 hours of college course work, are required to enroll in the class.

The class engages entering students in critical inquiry of one or more related academic topics. The seminar is designed to increase students' knowledge of the role of technology in the academic community. Information acquisition, critical thinking, and communication are integrated in an active learning environment. Students conduct library and electronic research to support one or more academic projects which vary with instructor. Examples topic themes taught in the Fall 2000 semester include Teamwork and Management of Teams in Engineering, Future World Crises, and Renewable Energy Technology and Global Environmental Issues.

Seminar in Critical Inquiry is woven together by five goals incorporating thirteen objectives. Five of the objectives are required of all sections; all other objectives are highly recommended. In the following, the required objectives are identified by an asterisk (*).

GOAL 1. To strengthen students academic performance and facilitate their transition to college.

- Objective 1.1 Students will explore one or more academic topics to become aware of and practice the habits of scholarship.
- Objective 1.2 Students will become familiar with major UTEP academic policies and requirements.
- Objective 1.3 Students will examine personal and social transition issues affecting college success that could include topics such as academic expectations, high-risk behaviors, and relationships.

GOAL 2. To enhance students essential academic skills.

- Objective 2.1* Students will engage in critical thinking/problem-solving activities.
- Objective 2.2* Students will practice oral, written, and electronic communication skills.
- Objective 2.3* Students will conduct library and electronic research.
- Objective 2.4* Students will examine and develop academic survival and success strategies (e.g., note-taking, active reading, time management).

GOAL 3. To increase student/student and student/faculty interaction both in and outside of the classroom.

- Objective 3.1* Students will meet at least twice with the course instructor to discuss academic progress and transition to UTEP and to explore options for improvement.
- Objective 3.2 Students will participate in group activities and learn more about group roles and facilitation skills.

GOAL 4. To encourage students self-assessment and goal clarification.

- Objective 4.1 Students will participate in at least one activity to assess learning styles and relate them to college tasks.
- Objective 4.2 Students will participate in at least one career assessment activity that examines the students interests, abilities, and values.

GOAL 5. To increase students involvement with UTEP activities and resources.

- Objective 5.1 Students will attend/participate in social, cultural, and intellectual events at UTEP.
- Objective 5.2 Students will become aware of and use selected academic and student support resources.

The seminar class is in a sense the glue of the cluster grouping. In the seminar class, base groups are usually established, the essential ingredients of academic success are learned, and the recipe for success is created. Within the surrounding cluster classes, the techniques and skills promoted within the seminar are practically applied. The seminar thus provides something of a home classroom environment for the entering students. Instructors of the seminar classes assume primary responsibility for promoting face-to-face interaction with other cluster faculty as well as students. The seminar class often provides the first level of support for students attempting to grapple with the new academic world of university studies.

As an example, time management is critical to student success. In the seminar class, students are engaged in self-analysis of their time commitments, share their results with other students, and then, establish strategies for successfully managing their schedules. Within the cluster classes, the practice of meeting deadlines is practiced which reinforces the principles of time management. Other examples include the use of electronic communication which is introduced early in the class (e-mail interaction with the seminar teaching team is established) and then practiced in the other cluster classes. The use of library research techniques, learned in university seminar sessions, is practiced in the English composition and *Introduction to Engineering* courses.

In this way, there is parallel reinforcement of crucial student success skills. The occurrence of four classes in the cluster only serves to strengthen the opportunity for cross fertilization of teaching strategies for success. It does, however, require the commitment of faculty to interact during the semester, in addition to joint planning sessions prior to class commencement. In our experience, the use of peer facilitators as mediators in this interaction greatly assist this process.

Introduction to Engineering

Introduction to Engineering is a developmental course specifically designed to fit in the four-course Intermediate Algebra Cluster and cannot be counted as credit toward an engineering degree. The course targets a math level of high school algebra II. The primary goals of the course are to serve as a bridge between the abstract concepts learned in math and their application to practical, "real world" problems, to provide extensive practice in setting up and solving a wide variety of applied problems, and to explore careers in engineering and computer science. The specific objectives of the course include:

- Reinforce the learning, success, and team skills learned in the seminar course,
- Develop problem solving strategies,
- Introduce units as an integral part of problem solving,
- Develop the ability to translate a word problem into an algebraic equation,
- Practice solving progressively more complicated algebraic equations,
- Master the use of a graphing calculator,
- Apply math knowledge to solve progressively more difficult applied problems,
- Introduce engineering-type written and oral communication, and
- Explore engineering and computer science careers.

This course reinforces the learning, success, and team skills learned in the seminar course by simply requiring the practice of these skills in *Introduction to Engineering*. The instructors for the two courses share their syllabi, coordinate activities, and communicate on at least a weekly basis. Thus, the students receive double exposure to these critical skills.

The ability of the students to apply math concepts to practical problems was increased through a variety of activities. First, the students were introduced to a procedure for solving problems and were required to use a specific format in setting up and solving problems. Then, they were introduced to the S.I. and U.S. unit systems and required to use units in all of their solutions. The ability to make unit conversions was developed by including units from both systems in most problems. Next, students were introduced to the concept of significant figures and were required to report all answers using appropriate significant figures. Problems involving area and volume of the common two-dimensional and three-dimensional shapes were used to develop the students problem solving technique at a basic level.

The next step was to develop the students' ability to translate word problems in algebraic equations and to improve their ability to manipulate and solve complicated algebraic expressions. This was accomplished by creating a wide variety of word problems. Initially, the problems involved simple mixtures (coins, stamps, fruit, etc.) and ratios. Then, rate problems involving time, distance, and speed, as well as, time, volume, and volumetric flow were introduced. Also, problems involving moments were included.

Once the students' problem solving ability began to develop, they were introduced to hands-on projects. This required them to determine what the problem was and then translate it into an algebraic equation. The projects also required that they make assumptions and estimates. The students were required to submit both individual and group reports on some of the projects.

In order to explore career options, the students were divided into groups by intended major. Each group researched a career in their chosen discipline and wrote a report. The groups then prepared and gave oral presentations on their report using PowerPoint.

In order to determine the success or failure of *Introduction to Engineering* in addressing the needs of the students, an end-of-course survey was administered. Students were asked to compare their knowledge/ability at the end of the course with their knowledge/ability at the beginning of the course on seventeen items that were covered in the course. The answer choices were No Change, Slightly Better, Better, Much Better or Much, Much Better. Choices Much Better and Much, Much Better received high percentages for all items in the survey. The results for selected key items are given in Table 1.

A serious concern about the *Introduction to Engineering* course was that the work required of students in the course might interfere with their performance in *Intermediate Algebra*. Figure 4 shows the results of a survey question focused on this concern. None of the students indicated that *Introduction to Engineering* caused problems in *Intermediate Algebra,* while 77.1% reported that *Introduction to Engineering* either Helped or Helped A Lot in Intermediate Algebra.

Table 1. Students comparison of knowledge/ability at the end of course with their knowledge/ability at the beginning of the course.

Knowledge/Ability	No Change	Slightly Better	Better	Much Better	Much, Much Better
Using units	4.1%	8.2%	16.3%	36.7%	34.7%
Making conversions	4.0%	6.0%	8.0%	46.0%	36.0%
Solving complex algebraic equations	2.0%	6.1%	24.5%	42.9%	24.5%
Translating word problems into algebraic equations	4.1%	6.1%	20.4%	36.7%	32.7%
Combining two or more concepts	4.3%	2.1%	23.4%	38.3%	31.9%

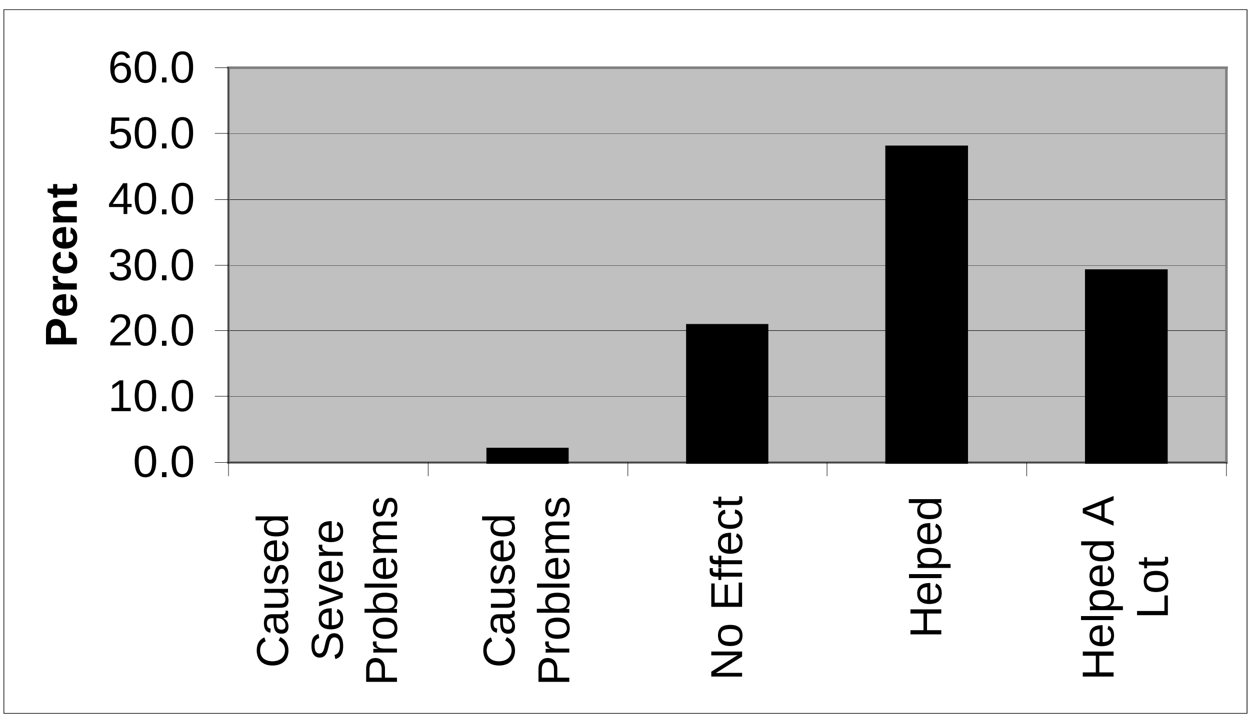

Figure 4. Effect of *Introduction to Engineering* on students' performance in *Intermediate Algebra*.

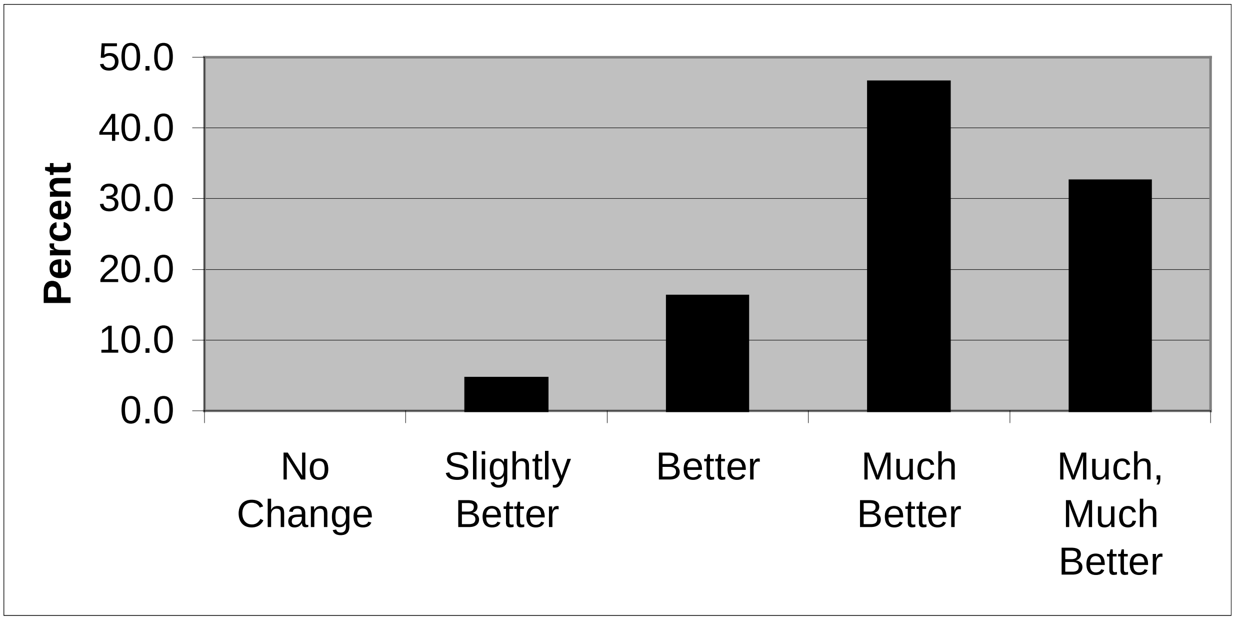

Figure 5. Effect of *Introduction to Engineering* on students' understanding of what it takes to become an engineer or scientist.

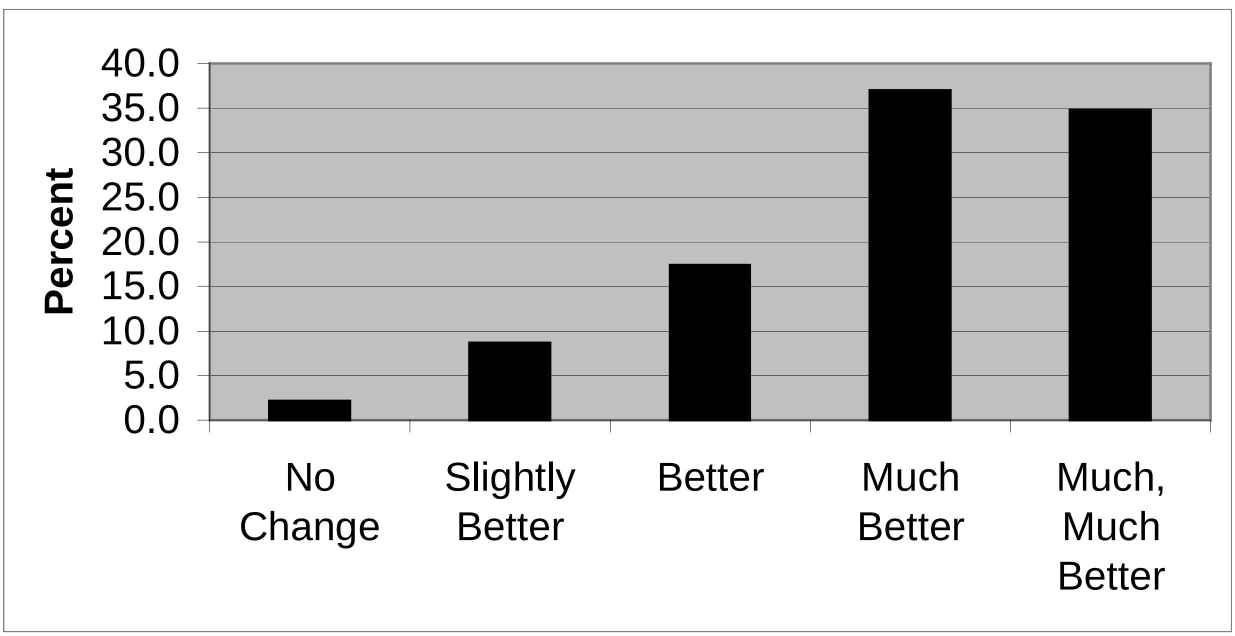

Figure 6. Effect of *Introduction to Engineering* on students' understanding of their chosen engineering major.

Figure 5 shows that *Introduction to Engineering* was successful at helping students' to understand what it takes to become an engineer or computer scientist. The course was also successful at helping students' understand their chosen engineering discipline as shown in Figure 6.

Summary

Clustering of entering engineering freshmen in a group of three or four courses taught by dedicated faculty changes the university environment from what might be termed uncaring and hostile to one that is user-friendly and supportive. Although students initially resist the cluster concept and make fun of team building, by the middle of the semester all the students are familiar with each other and know each others names. The instructor has developed a close relationship with his or her students and the peer facilitator has become a friend, mentor, and tutor. Students are studying together, having lunch together, and are involved in social activities together on a regular basis. They help each other through day-to-day crises and become intertwined in each others lives, in addition to becoming focused on the common goal of succeeding in college. They develop a learning community that sustains them throughout their education and they develop lasting friendships.

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