The Effect of a First-Year Integrated Engineering Curriculum on Graduation Rates and Student Satisfaction: A Longitudinal Study

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ABSTRACT

This paper reports on the long-term results of a two-year experiment conducted in the 1994–1995 and 1995–1996 academic years in which a group of "average" engineering students was recruited for a first-year program that integrated curricula and fostered a learning community. Students who participated in the *Connections* program graduated at a significantly higher rate than their peers and reflected retrospectively that the program had a strong positive effect on their college careers.

I. INTRODUCTION

In 1993, in response to nationwide concern about the inadequate number of students majoring in STEM (science, technology, engineering, and mathematics) disciplines, the Colorado School of Mines (CSM) undertook a pilot program intended to increase the retention and graduation of a group of "average" engineering and science students. Called *Connections*, the program focused on integrating the first-year curriculum while maintaining separate courses and on increasing the sense of community among student and faculty participants.

The intellectual rationale for this program was straightforward: we tried to provide our students with a more meaningful first-year experience by allowing them to discover and explore important connections among the humanities, physical and social sciences, and engineering subjects they studied in their first year at CSM. Our desired result was that *Connections* students would acquire a deeper appreciation of the importance of these subjects and their interrelatedness in their upper division courses, their professional engineering work, and their lives.

In addition, we wanted to provide a supportive learning community for the students. We hoped that as a result of close student-student and student-faculty interactions, we would achieve the four outcomes that Tinto [1] associates with successful learning communities: formation of self-supporting groups; more active involvement in classroom learning than other students; enhanced quality of student learning; and higher persistence rates than comparative students in the traditional curriculum.

Students were involved in the *Connections* program only in their first-year at CSM; no additional activities were included in their subsequent college careers. However, our current follow-up study found that *Connections* students graduated at a significantly higher rate than their peers in a comparison group. Although we cannot prove decisively that the *Connections* program was responsible for this difference since our project was implemented as action research and we did not use a pure "treatment group/control group" design, we believe that we have a strong case for the influence of *Connections* on student performance. This paper describes the project and then reports on our follow-up study of two groups of students focusing on their graduation rates compared to a CSM comparison group as well as their post-graduation reflections on the program.

A. Background

The state of engineering education in this country has come under intense scrutiny in recent years, particularly as it influences our ability to compete in global high-technology markets. In the mid-1990s, as we were planning this project, several well-respected groups, including the National Science Board's Task Committee on Undergraduate Science, Mathematics, and Engineering Education [2], the American Society for Engineering Education Task Force [3], the National Congress on Engineering Education [4], the Sigma Xi National Advisory Group [5, 6] and the Association of American Colleges (AAC) [7] all called for changes in ways we prepare engineers for the future.

Two themes arose in many of these reports: 1) undergraduate engineering curricula generally do a poor job of integrating curricular topics in any meaningful way, and 2) freshman instruction is often delivered in ways that discourage students from pursuing careers in science and engineering.

The Sigma Xi National Advisory Group [5] summarized several characteristics of lower division curricula that drive away potential engineering and science students. These characteristics include:

- large, impersonal classes;
- failure to stimulate and engage students;
- emphasis on memorizing irrelevant course content, with no attention to the processes of investigation (analysis, synthesis, critical reasoning);
- fragmented course offerings with no indication about why the courses are important to an engineer or how they are related to each other; and

- no introduction to engineering problem-solving methodologies and thus no indication of what engineers can and cannot achieve

Hewitt and Seymour [8] reported that the leading reasons cited by a sample of about 150 lower division students switching out of STEM (science, technology, engineering, mathematics) majors were: 1) non-technical majors offer a better education, 2) loss of interest in science, and 3) rejection of technical careers. Poor teaching and unapproachable faculty members were also cited as important reasons for opting out of engineering.

The net result of poor freshman retention is fewer students on the engineering "pathway" and lower graduation rates. Recent statistics indicate that while some progress has been made in the decade since the *Connections* program was conceived, the number of students interested in engineering careers is still low. Of the students taking the ACT or SAT in 2001, 12 percent of men and only 2 percent of women were planning to major in engineering [9]. Although the number of students graduating with degrees in engineering has risen every year since 1999 (up to 67,301 in 2002, bringing the numbers close to the 70,000 mark that has not been achieved since 1988) [10], data from the Higher Education Research Institute at UCLA quoted in *Prism* magazine show that student interest in engineering has declined nearly one-third since the early 1980s. Only 7.3 percent of 2001 freshmen indicated an interest in studying engineering [11]. Based on past trends, only about 50 percent of those entering college intending to major in engineering can be expected to eventually earn a B.S. engineering degree.

According to the National Science Board's *Science and Engineering Indicators 2002*, "The Center for Institutional Data Analysis and Exchange (C-IDEA 2000) at the University of Oklahoma recently released a report of its longitudinal study, conducted from 1992 to 1998, of a cohort of college students. The study aimed to gather benchmark statistics on retention rates in science, mathematics, engineering, and technology disciplines. Researchers surveyed 119 colleges and universities ranging from small to large, liberal admission to highly selective admission, and bachelor's degree only to doctorate-granting institutions.

The report states that "In 119 colleges and universities, about 25 percent of all entering first-time freshmen in 1992 declared their intention to major in a science and engineering (S&E) field. By their second year, 33 percent of these students had dropped out of an S&E program. After six years, 38 percent had completed an S&E degree. Women and underrepresented minorities dropped out of S&E programs at a higher rate than men and non-minority students. Consequently, degree completion rates in S&E fields were lower for women (35 percent) and underrepresented minorities (24 percent)" [12].

Clearly, engineering schools in this country cannot continue to ignore a sizable portion of our intellectual talent if the United States is to maintain a leadership role in STEM disciplines. Simply put, we must do a better job of attracting, retaining, and graduating the best engineering students available, including women and underrepresented minorities. Just as clearly, these efforts must be concentrated in the lower division (particularly first-year) courses where many students with interest and aptitude in science and engineering are lost. It is in response to these ongoing problems that the Colorado School of Mines (CSM) developed the *Connections* program and received funding from FIPSE (Fund for the Improvement of Post-Secondary Education) to help support our efforts.

II. Project Context and Overview

A. The CSM Context

The Colorado School of Mines (CSM) is a small, state-assisted institution in which all students take a common core of courses and major in engineering, applied science, or economics. The undergraduate student body, consisting of approximately 2,500 students, attracts freshmen ranking in the 90th percentile in mathematical skills and 80th percentile in verbal skills on the SAT and ACT examinations.

In the mid-1990s, faculty, students, and administrators at CSM developed a new academic plan based on the goals described in its Profile of the Future Graduate. The profile articulates the following attributes we expect all graduates of the school to possess [13]:

- Depth in an area of specialization, enhanced by hands-on experiential learning, and breadth in allied fields; knowledge and skills to be able to recognize, define and solve problems by applying sound scientific and engineering principles.
- Skills to communicate information, concepts and ideas effectively orally, in writing, and graphically; skilled in the retrieval, interpretation and development of technical information by various means, including the use of computer-aided techniques.
- Flexibility to adjust to the ever-changing professional environment and appreciate diverse approaches to understanding and solving society's problems; creativity, resourcefulness, receptivity and breadth of interests to think critically about a wide range of cross-disciplinary issues; possess the skills and attitudes which promote teamwork and cooperation and to continue growth through life-long learning.
- Capability to work effectively in an international environment and be able to succeed in an increasingly interdependent world where borders between cultures and economies are becoming less distinct; appreciation of the traditions and languages of other cultures, and value diversity in their own society.
- Exhibit ethical behavior and integrity; demonstrate perseverance and have pride in accomplishments; assume responsibility to enhance their professions through service and leadership and be responsible citizens who serve society, particularly through stewardship of the environment.

It was our belief that achieving these goals would, by necessity, require an interdisciplinary approach involving the physical and social sciences, humanities, and engineering. We believed that in the future, our graduates would need to better understand the interrelatedness of human knowledge and be capable of applying knowledge and skills from numerous disciplines to solve problems and improve the quality of life for the world's inhabitants. To graduate engineers with these attributes, we needed to provide an integrated educational experience in which students explored the connecting points among disciplines as they became more proficient in those disciplines. Thus, the goals of the *Connections* program conceptually related to the mission and academic plan of CSM by encouraging first-year students to:

- discover and develop significant connections among their first-year core subjects;
- enhance their higher order thinking abilities and apply these abilities in humanistic, scientific, and engineering contexts;
- understand the historical and cultural contexts which have influenced developments in science, humanities, and engineering;

- struggle with some of the world's great ideas and issues;
- further develop their sense of ethics and values, particularly concerning the applications and limitations of technology in the modern world; and
- improve their oral and written communication skills.

B. The CSM First-Year Curriculum

To understand how the *Connections* program was designed to help students form connections in their first-year courses, it is important to first describe the traditional CSM first-year curriculum in place during our study (1994–96). All CSM students were required to take introductory courses in mathematics, chemistry, physics, earth systems, and economics. They also completed interdisciplinary course work in humanities and engineering practices.

When this project was conducted, the introductory humanities course was entitled "Crossroads" and provided first-year students with an introduction to literature and philosophy; world history; and science, technology and society. The emphasis was on a broad-based exploration of these disciplines to prepare students for advanced work in humanities and social sciences. Engineering practice was introduced in a four semester, 11 credit-hour sequence entitled EPICS (Engineering Practices Introductory Course Sequence) required of all first- and second-year CSM students. The program was designed to enhance engineering students' abilities in: 1) open-ended problem-solving, 2) oral, written, and graphical communications, and 3) team processes.

Although all of the first-year courses met their objective of teaching the material listed in their syllabi, each course was traditionally designed and taught as a self-contained body of knowledge and analysis with no organized attempt to help students make connections to related topics in other courses. Faculty members teaching the courses believed that these crosscutting topics were important and that many of them would eventually influence each student's education and professional practice. The students, however, tended to see each course (and most topics within each course) as a list of distinct, unconnected islands of information to be learned for an exam and then forgotten. Not surprisingly, CSM students, like many other engineering students, often questioned WHY they were required to complete many of their first-year course requirements, a question that often was never answered explicitly during their academic career. The *Connections* program represented our attempt to help students understand the importance of their first-year studies by allowing them to develop appropriate and significant links among disciplines.

C. Features of the Connections Program

To achieve the objectives of *Connections*, we: 1) *modified* existing first-year course syllabi to feature a series of integrated project modules which allowed students and faculty to explore appropriate connections among these disciplines, 2) *taught* a two-semester *Connections* interdisciplinary seminar series in which students and faculty further developed and explored the interconnectedness of appropriate topics from each of the first-year science, humanities, and engineering courses, 3) *modified* existing pedagogical practices (primarily passive lectures in most courses) to include extensive use of active-learning and cooperative learning strategies, team-teaching, and writing as a learning and inquiry tool and, 4) *developed* a peer study group system to encourage interpersonal growth and support among *Connections* students. As shown in Figure 1, the CSM first-year curriculum was transformed from a collection of unconnected boxes to an interconnected web of concepts centered on the *Connections* seminar.

It is important to note here that the revised curricular structure maintained the disciplinary integrity of each first-year course and therefore could be adapted to fit a variety of core curriculum configurations.

D. Connections Modules

Project modules were developed to allow students to apply what they were learning in individual courses to interdisciplinary problems and issues posed in each module. The following modules were developed and tested [brackets indicate which courses are connected in the module]:

- remediation of groundwater contamination [chemistry, geology, EPICS, Crossroads]
- analysis, evaluation, and ramifications of pollution data [chemistry, geology, Crossroads]
- passive solar collector design [mathematics, EPICS, Crossroads]

Each module was carefully designed to allow students an opportunity to immediately apply knowledge from their technical and liberal arts courses in interdisciplinary contexts. For example, the

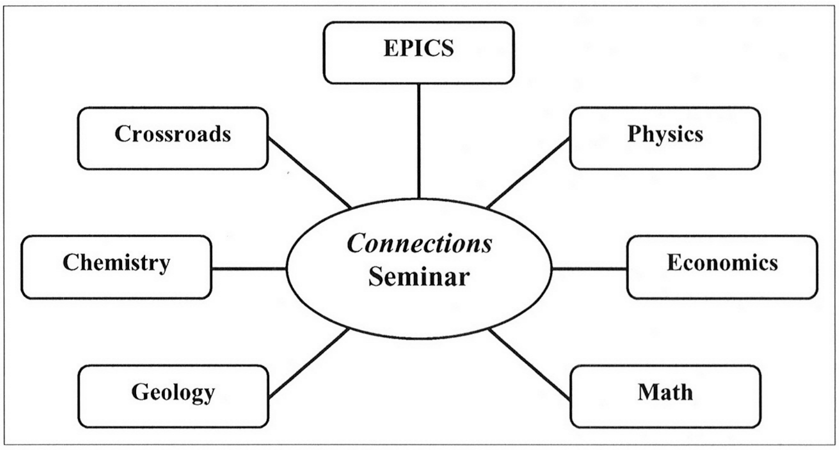

Figure 1. Connections *first-year curriculum.*

groundwater remediation module allowed students to explore connections among geology, mathematics, chemistry, economics, humanities, and social sciences by studying the process of groundwater flow and contaminant transport in an established mine tailing site. Students developed a simple remediation plan for the site using geological, mathematical, and chemical principles to analyze groundwater flow and contaminant transport processes. Social and political issues related to the existence and maintenance of polluted sites in populated areas were discussed and they examined the kinds of constraints and considerations which govern how humans choose to utilize the earth's renewable and non-renewable resources and the effects of utilization on the environment.

We also discussed potential trade-offs required to balance quality of life and environmental quality and the implications of these trade-offs for the future. Alternative methods for evaluating the economic costs associated with remediation of contaminated sites were analyzed and the cleanup costs of the site remediation plan being developed were estimated using two economic models (cost/benefit analysis and least cost analysis). Completion of this module helped students understand that effective environmental protection strategies require an interdisciplinary approach involving science, engineering, humanities, and social science.

E. Connections *Seminar*

The *Connections* seminar met weekly using a small group discussion format to allow students to reinforce connections introduced via the modules and to develop additional connections across traditional disciplines. Themes discussed in the *Connections* seminar included:

- biographies of role models in science and engineering;
- method in humanities, social sciences, physical sciences, and engineering;
- history of science and technology focusing on the scientific, industrial, and Darwinian revolutions; and
- an interdisciplinary analysis of the "limits to growth" argument originally posed by the Club of Rome.

For example, as students explored the concept of "method" in various disciplines, they read excerpts from Kuhn [14] (scientific method), Koen [15] (engineering method), Hoover [16] (social science method), and Ciardi [(17] (humanities method). After discussing these selections, students developed hypotheses about the kinds of problems posed and solved by professionals in different disciplines and about how evidence is valued and utilized in different ways. Students later tested their hypotheses by interviewing CSM faculty members willing to discuss their personal philosophies of problem-solving methods. These findings were shared with other students in the seminar who ultimately gained a better understanding of the similarities and differences among problem-solving methods in the disciplines. Perhaps more importantly, our students also began to understand *why* we should all understand something about methods in disciplines other than our own.

Students in the seminar also read from the biographies of physical scientists [M. Curie, Feynman, Priestley, Kovalevskaya, Hutton], social scientists [Benedict, Keynes], an engineer [Amman], and a humanist [M. Shelley] as they learned about the human dimension of professional role models. They read from Whitehead, Lewis, and Ferris [scientific revolution], Toynbee [industrial revolution], and Darwin and Mayr [Darwinian revolution] as they discussed the impacts of these revolutions on our lives and they studied the writings of Myers and Simon as they debated the "limits to growth" issue. The *Connections* seminar was our primary vehicle for encouraging inquiry beyond the level of integration obtained using project modules in the first-year courses. Each seminar group consisted of 15–18 students and two or three faculty members who were involved in teaching *Connections* courses. Students were required to keep a journal throughout the year in which they recorded their reflections on readings, discussions, and coursework.

F. Faculty Development Activities

Prior to teaching first-year courses for *Connections* students and the *Connections* seminar, each faculty member who participated in the program attended at least one first-year course taught by another *Connections* faculty member. As we sat in each other's classes, we became aware of the course content, skills, pedagogies, and issues emphasized in each course. Although we tried to complete much of the coursework (readings, homework, and laboratory exercises), each of us concentrated on observing the "big picture" in the course and watching for possible connections with our other courses. In addition, some of us also worked diligently to learn the course content to better help us in our own *Connections* courses and the *Connections* seminar. Our observations have been published elsewhere [18] and are summarized here. We all agreed that we had misperceptions about each other's first-year courses on at least two levels—faculty and students. Among the faculty, we noted disagreements about appropriate and effective pedagogies, the definition and achievement of "teaching" and "learning", our expectations of the students, student maturity, effective testing, and the goals of education.

We also clearly perceived the courses we audited differently than our students did. We found intrinsic value in the material presented while they worried about whether it would be on the exams; we saw the "big picture" while they were often bogged down in details; we respected each other while they often displayed a "show me" attitude. We expected the students to be mature learners while they reminded us in their actions and words that they were just out of high school and sometimes not nearly as adult as we assumed. Such discoveries were important to us as faculty both within and outside of the *Connections* program.

We all concluded that the auditing process, while difficult to complete given our typically overloaded schedules was worthwhile and that we ultimately learned a great deal about the course content, about learning, about our students, and about ourselves as teachers.

III. The Pilot Courses

A. First Pilot Course, 1994–95

After a year of intense planning and curriculum development, we offered the first *Connections* pilot courses during the 1994–95 academic year. Forty-nine CSM first-year student volunteers were admitted into the program from an initial pool of 299 eligible students (those incoming first-year students who did not require remediation or have advanced placement credit for any of the first-year core courses). The selection process is discussed in more detail in the Discussion section. As a rule, our students attended specially designated sections of each first-year course that were closed to non-*Connections* students. The exceptions were large lectures in economics, chemistry, physics, and geology. For these courses, our students attended lectures with other CSM first-year students, but worked in "*Connections* only" recitations and laboratory sections. Modules were introduced into the appropriate courses according to an established timetable developed by the *Connections* faculty who continued to meet bi-weekly to coordinate course schedules and deal with problems and issues.

Each faculty member also participated as a seminar moderator or co-moderator so that we met with our students in both a disciplinary context in our classes and an interdisciplinary context in the seminar. The weekly seminar schedule for the first pilot course is shown in Table 1. We found that the combination of modular work in classes combined with further exploration of relevant issues in a discussion-based seminar environment enhanced our interactions with students and their ability to make meaningful connections among topics in many disciplines.

Many of our students in the first pilot group commented that an important motivation to participate in *Connections* was the opportunity to meet and work closely with faculty and fellow students. They were less concerned about the scholarly connections than the social ones. We observed many of our students forming closely-knit study groups and friendships during their first year in the program, friendships that continued as the students moved into upper-division courses. *Connections* students also tended to talk to the faculty or communicate by e-mail more than do traditional first-year students. Overall, we were able to get to know our students much better and this helped create a context of trust in which we all learned from one another in our courses and seminars.

B. Second Pilot Course, 1995–96

Informal student feedback and input from our external evaluator (Dr. Gloria Rogers from the Rose-Hulman Institute of Technology) indicated that students in the program desired more social connections and support (e.g., mentoring and advising; team-building; academic success strategies) in addition to learning about intellectual and academic connections. Thus, in the second year the program focus shifted somewhat away from an emphasis on content and towards an emphasis on developing a learning community, which, as described by Love, involves "working collaboratively toward shared, significant academic goals in environments in which competition, if not absent, is at least de-emphasized. In a learning community, both faculty and students have the opportunity and the responsibility to learn from and help teach each other." [19]

According to The Learning Community Commons Web site [20], "In higher education, curricular learning communities are classes that are linked or clustered during an academic term, often around an interdisciplinary theme, and enroll a common comparison group of students. A variety of approaches are used to build these learning communities, with all intended to restructure the students' time, credit, and learning experiences to build community among students, between students and their teachers, and among faculty members and disciplines." The Learning Community

Week	Fall Semester topics (2 class hours per week; 2 credit hours)	Spring Semester topics (2 class hours every other week; 1 credit hour)
1	Introduction to Connections seminar; goals and expectations	Introduction to spring semester Connection seminar
2	Introduction to critical thinking	
3	Classroom connections I (emphasis on math and physics)	Introduction to Revolutions (scientific, industrial, Darwinian)
4	Introduction to biographies of scientists, humanists, social scientists, and engineers	
5	Preparation of biographical mini-plays	Continuation of revolutions discussion
6	Performance of mini-plays	
7	Classroom connections II	Oral presentations from groups studying each revolution
8	Introduction to primary questions of method in various disciplines	
9	Group work on method	The Next Revolution (speculation on the future)
10	Oral and written reports on faculty interviews	
11	Introduction to structured controversy project on the greenhouse effect	Introduction to "Limits to Growth" debate; establish hypotheses based on this research
12	Structured controversy group work and discussion on greenhouse effect; analyze available data	
13	Full class discussion to wrap-up analysis of greenhouse effect	Team oral and written presentations supporting proposed hypotheses
14	Oral reports on results of structured controversy discussion	
15	Individual written reports on structured controversy; celebrate end of semester	Celebrate end of school year

Table 1. Weekly class schedule for Connections *seminar (1994–95 pilot version).*

Commons goes on to describe three general types of learning communities in higher education: 1) student cohorts/integrative seminar (students are enrolled in larger classes not coordinated by the faculty but may meet in an additional integrative seminar); 2) linked courses/course clusters (two or more classes linked which are collaboratively planned by faculty and which a cohort of students takes together; and 3) coordinated study (team-taught courses in an integrated course of study). Additional information on learning communities can be found in work reported by Tinto, [1], Bystrom [21], Gabelnick, et al. [22], and Schroeder, et al. [23], among others.

We made several changes in course philosophy, structure, and content to reflect the shift toward community building before delivering an updated *Connections* program during the 1995–96 academic year. These changes combined features of each type of learning community described above and included a major revision of the seminar to focus on developing the proper support structure for student success before concentrating on developing connections among academic topics and courses. The revised seminar syllabus is summarized in Table 2. We also made available to the students more explicit mentoring and tutoring help in addition to formal seminar sessions.

We utilized a text by Dr. Raymond Landis entitled "Studying Engineering: A Road Map to a Rewarding Career" [24] for this portion of the seminar. The *Connections* section of Crossroads (the first-year introductory humanities/social science course) was also completely restructured to include readings and discussions directly relevant to our seminar work and work in other courses. Thirty-one volunteer first-year students from an available pool of 256 students were admitted into the second version of *Connections* courses beginning fall semester 1995. Once again, our students attended specially designated sections of each first-year course. The modules on remediation of groundwater contamination and passive solar collector design were revised and introduced into the appropriate courses. *Connections* faculty continued to meet bi-weekly to coordinate course schedules and deal with problems and issues. Once again, each faculty member participated as a seminar moderator or co-moderator so that we met with our students in both a disciplinary context in our classes and an interdisciplinary context in the seminar.

Week	Fall Semester topics (1 class hour per week; 1 credit hour)	Spring Semester topics (2 class hours alternating weeks; 1 credit hour)
1	Introduction to Connections; meet with mentor	Introduction to Connections spring semester program; debrief fall semester seminar and courses; meet with mentors
2	Icebreaker; keys to success in engineering study	
3	Discuss value of collaborative learning and study groups	Math/physics connections
4	Exam preparation – chemistry and economics	
5	Calculus connections – I	Exam preparation strategies
6	Debrief first round of exams; take Academic Success Skills survey in Landis and discuss; introduce methods/biography project	
7	Continue methods/biography discussion; assign biographies to read	Introduction to revolutions module; team selection; distribution of readings
8	Students teach each other about the biographies for which they were assigned; prepare questions for panel discussion	
9	Panel discussion with prominent engineer, scientist, humanist; questions focus on method in different disciplines	Teamwork on revolutions module
10	Wrap up discussion of method; meet with mentor to plan pre-registration for spring semester	
11	Calculus connections – II	Oral presentations on team findings
12	No seminar – students participate in school-wide presentations on selecting a major	
13	Time management; chemistry exam preparation	Discussion of "next revolution" possibilities; final exam preparation
14	Thanksgiving week – no seminar	
15	Final exam preparation; celebrate end of the semester	Celebrate end of school year

Table 2. Weekly class schedule for Connections *seminar (1995–96 pilot version).*

IV. Results and Discussion

Since *Connections* was an ambitious and unique modification to the CSM first-year curriculum, we evaluated the project using both formative and summative evaluation techniques including student academic performance (grade point averages and retention rates), student perceptions and attitudes about issues addressed in *Connections* courses and seminars (surveys, journals, informal interviews, focus groups), and faculty feedback. In general, students in the program praised the dedication and expertise of the faculty, the opportunity to make new friends with other students early in their college careers and several of the seminar topics and modules. Details of these results have been reported elsewhere [25–27].

We focus in this paper on an analysis of the graduation data for the *Connections* students and comparison groups and on the findings of a follow-up longitudinal survey we administered to students from both *Connections* pilot courses. The survey was administered by mail in 2000 after all but one of the *Connections* students had graduated or left the school without graduating. The purpose of the survey was to acquire feedback from the students as they reflected on the program and its impact on their academic life and the beginning of their professional careers. In particular, we were interested in trying to explain the significant increase in graduation rates of *Connections* students compared to CSM comparison groups who entered school in 1994 and 1995.

A. The Selection Process

As discussed earlier, students in both years were selected for the *Connections* program from the pool of all entering first-year students who did not require remediation or have advanced placement standing. About 50 percent of each entering class met our criteria for "average." This selection process was used for two reasons, one philosophical, one practical. Philosophically, we wanted to deal with students who, while certainly above average in terms of the general population, were "average" CSM students; we believed that if our program could work with them, it could also succeed with students on the two tails. Practically, we needed students who were all registered for the same classes so that we could deliver the complete *Connections* curriculum.

All students who met our criteria for participation were invited by letter prior to the beginning of fall semester courses. This solicitation generated pools of students from which we randomly selected students for *Connections*. Each pool of volunteers was approximately 30–40 percent larger than the ultimate class size we taught each year.

B. Graduation Rate and Academic Performance Results

Four-, five-, and six-year graduation rates for *Connections* students who participated in the two pilot courses are summarized in Tables 3 and 4. Of the 49 students in the first pilot group, 36 graduated from CSM within five years, 12 did not complete a degree and left CSM, and one was still enrolled after six years of study. In the second pilot group of 31 students, 26 students graduated within five years and five left the school without earning a CSM degree.

Tables 3 and 4 also summarize graduation rates for a comparison group of CSM students who matriculated at CSM in 1994 and 1995, respectively. For purposes of this study, the comparison group was defined as any first-year student who did not register for any remedial or advanced placement courses and who was eligible to participate in *Connections* but declined or was not randomly selected from the pool of students who volunteered to participate in the program. We were unable to retrospectively identify a true "cohort" for this analysis, which would have consisted solely of students who applied for the *Connections* program but were not selected. As shown in Table 3, the differences between the first *Connections* group and comparison group students are mixed. The five-year graduation rate for *Connections* students is significantly higher than for the comparison group, while the four- and six-year rates are not. However, even after six years at CSM, the comparison group graduation rate was still nearly nine percent less than the *Connections* student rate.

As Table 4 indicates, the graduation rate for the second group of *Connections* students is nearly 84 percent after five years, which is consistently and significantly higher than the rate for the comparison group. The *Connections* graduation rates compare even more favorably with the overall five-year graduation rate for the entire CSM class entering in 1994 of 56 percent and the rate for the entire class entering in 1995 of 60 percent. Graduation rates for *Connections* students are particularly remarkable given the "average" first-year

Time to graduation	Percentage of *Connections* students graduating (n = 49)	Percentage of 1994 comparison group graduating (n = 250)	Statistical comparison[1]
4 years	24.5	32.0	do not reject H_0 ; p=.851
5 years	73.5	60.8	reject H_0 ; p=0.047
6 years	73.5	64.8	do not reject H_0 ; p=0.120

[1] Hypothesis test of proportions:

H_0: Connections graduation rate = comparison group graduation rate

H_1: Connections graduation rate > comparison group graduation rate

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 3. Graduation rates of 1994–95 Connections *students compared with 1994 first-year comparison group.*

students recruited into the *Connections* program and the fact that there was no special treatment of these students after their first year at CSM.

Note that the statistical comparisons in Tables 3 and 4 are based on one-sided t tests of proportions (i.e., graduation rates defined as graduating students divided by total students in a population). Our choice of one-sided tests was based on the premise that we were analyzing the data to determine whether *Connections* students graduated in significantly higher proportions than the comparison group. Two-sided tests results provide the same conclusions as results summarized in Tables 3 and 4.

We also compared the five-year graduation rates of the 1994–95 and 1995–96 *Connections* student groups and found the difference (83.9 percent vs. 73.5 percent) not to be statistically significant ($p = 0.281$) given the small sample sizes of students involved. Nevertheless, our interactions and discussions with the 2nd *Connections* group suggested that increased focus on community building and academic success strategies further enhanced the persistence of these students. This finding will be discussed further in the Discussion section.

Given the significant improvement in graduation rates for *Connections* students, we searched for possible explanations in terms of academic preparation (e.g., ACT, SAT scores) or academic performance at CSM (GPA at graduation). Tables 5 and 6 summarize ACT and SAT results for the 1994–94 and 1995–96 *Connections* students and their comparison groups. As indicated in these tables, test scores for *Connections* students and the first-year comparison groups were not statistically different in either 1994 or 1995. We found no evidence indicating that the students who chose to participate in the *Connections* program were academically different than other first-year students in the comparison groups.

Another potential influence on graduation rates was a difference in academic performance between *Connections* students and the comparison groups. To see if this effect existed, we compared the final grade point average of *Connections* graduates and the corresponding comparison groups. Results are summarized in Tables 7 and 8 for four- and five-year graduates (no *Connections* students graduated in year six so comparisons beyond five years are not possible). As the data show, academic performance of *Connections* students was not statistically different from the comparison groups with the exception of the five-year *Connections* graduates who participated in the first pilot course. These students had a slightly lower average GPA than their comparison group. Thus, we found no compelling evidence that the academic performance of the *Connections* students was superior to their peers. To us, this confirmed that the *Connections* students were "average" students who persisted in higher numbers than their peers.

C. Results of Longitudinal Survey

Since we found no statistically significant ACT/SAT or GPA data that could explain the dramatic increases in the graduation

Time to graduation	Percentage of *Connections* students graduating (n = 31)	Percentage of 1995 comparison group graduating (n = 225)	Statistical comparison[1]
4 years	45.2	29.3	reject H_0 ; p=.037
5 years	83.9	60.9	reject H_0 ; p=0.006
6 years	83.9	65.8	reject H_0 ; p=0.021

[1] Hypothesis test of proportions:

H_0: Connections graduation rate = comparison group graduation rate

H_1: Connections graduation rate > comparison group graduation rate

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 4. Graduation rates of 1995–96 Connections *students compared with 1995 first-year comparison group.*

Test	Connections students	1994 Comparison group students	Statistical comparison[1]
ACT composite	27.9 (n=44)	27.9 (n=198)	do not reject H_0 ; p=0.965
SAT total	1239 (n=35)	1249 (n=179)	do not reject H_0 ; p=0.610

[1] Hypothesis test of means:

H_0: Connections mean score = comparison group mean score

H_1: Connections mean score ≠ comparison group mean score

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 5. ACT and SAT scores for 1994–95 students.

Test	Connections students	1995 Comparison group students	Statistical comparison[1]
ACT composite	26.7 (n=24)	27.6 (n=183)	do not reject H_0 ; p=0.183
SAT total	1220 (n=21)	1242 (n=155)	do not reject H_0 ; p=0.329

[1] Hypothesis test of means:

H_0: Connections mean score = comparison group mean score

H_1: Connections mean score ≠ comparison group mean score

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 6. ACT and SAT scores for 1995–96 students.

	Connections students	1994 Comparison group students	Statistical comparison[1]
4-year graduates	3.28 (n=12)	3.38 (n=80)	do not reject H_0 ; p=0.512
5-year graduates	3.00 (n=24)	3.19 (n=72)	reject H_0 ; p=0.020

[1] Hypothesis test of means:

H_0: Connections mean score = comparison group mean score

H_1: Connections mean score ≠ comparison group mean score

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 7. Grade Point Average of 1994–95 students.

	Connections students	1995 Comparison group students	Statistical comparison[1]
4-year graduates	3.32 (n=14)	3.36 (n=66)	do not reject H_0 ; p=0.722
5-year graduates	3.24 (n=12)	3.14 (n=71)	do not reject H_0 ; p=0.341

[1] Hypothesis test of means:

H_0: Connections mean score = comparison group mean score

H_1: Connections mean score ≠ comparison group mean score

p-values reported are the probability of wrongly rejecting H_0 when it is true

Table 8. Grade Point Average of 1995–96 students.

rates of *Connections* students, we administered a follow-up survey in the fall of 2000 asking participants in the program to reflect about their experiences. The survey asked questions related to both the content and mentoring/learning community goals of *Connections*. Table 9 summarizes the return rate data for each *Connections* class; these rates are considered above average for this type of survey. Although the responses from both student groups about the original program goals focusing on content were positive, feedback about the mentoring and learning community facets were especially enthusiastic. We also interpreted the high survey return rates as an indication of students' continued interest in *Connections*.

In the first part of the survey, students were asked to respond to ten questions about the program using a Likert scale from 1 (not at all) to 5 (to a great extent). The results of the survey from the 1994 group are summarized in Table 10 and the results from the 1995 group are summarized in Table 11. To simplify the data presentation, we have aggregated the 1 and 2 responses ("not at all" and "a little") and the 4 and 5 responses ("to some extent" and "to a great extent"). The first six questions deal primarily with the content goals of the program while the last four focus on mentoring/learning community goals.

Clearly, students believed that *Connections* enhanced their academic preparation by helping them make connections among course topics, by improving their critical thinking abilities, by helping them set a context for their science and engineering studies, and by heightening their awareness of important historical and contemporary issues including ethical situations. They also believed that the increased amount of writing and speaking in *Connections* helped improve their communication skills.

Even though the majority of students agreed with each of the ten statements in the survey, we observed a clear difference between the six questions related to course content and the four questions related to social interactions in the program. The average percentage of "4" and "5" scores for the 1994 class was 63.0 percent for questions 1–6 and 80.2 percent for questions 7–10 while in the 1995 class, the average percentages were 70.9 percent for questions 1–6 and 90.3 percent for questions 7–10. These differences are statistically significant at the 95 percent confidence level ($p = 0.009$ and 0.007 for the 1994–95 and 1995–56 student groups, respectively). Particularly in the second pilot course where the seminar was redesigned to emphasize the role of faculty and peer mentoring and learning community development, students believed that social connections were more meaningful to them than the topical connections originally envisioned by the *Connections* faculty and as exemplified by the original learning objectives of the program.

The second section of the follow-up survey allowed students to provide open-ended responses to four questions:

- What positive memories, if any, do you have of *Connections*?
- What negative memories, if any, do you have of *Connections*?
- What influence, if any, did the *Connections* program have on your educational experience at CSM or elsewhere?
- What else would you like us to know about your *Connections* experience?

	1994-95 Class	1995-96 Class
Total students in the program	49	31
Number of students who received the survey because a valid mailing address was available	40	28
Number of students returning a completed survey (% of students who received the survey)	24 (60%)	18 (64%)

Table 9. Return rates for follow-up Connections *survey.*

	Percentage of Student Responses		
Question	**"Not at all"or "A little" (1) and (2)**	**Neutral (3)**	**"To some extent" or "To a great extent" (4) and (5)**
Connections helped me discover and develop significant connections among my first year core subjects.	26.1	26.1	48.8
Connections helped me to enhance my critical thinking abilities and apply them in a variety of contexts.	16.7	16.7	66.6
Connections helped me to understand the historical and cultural contexts that have influenced developments in science, humanities, and engineering.	4.2	37.5	58.3
Connections helped me to become aware of and think about important historical and contemporary issues and ideas.	8.4	29.2	62.5
Connections helped me to further develop my sense of ethics and values, particularly about technology in the modern world.	20.8	16.7	62.5
Connections helped me to improve my oral and written communication skills.	8.2	12.5	79.2
I spent time outside of class socializing with members of my *Connections* group.	12.5	4.2	83.3
I spent time outside of class learning with members of my *Connections* group.	16.6	8.3	75.0
The quality of my learning at CSM was enhanced by my interactions with the other *Connections* students.	12.5	8.3	79.1
The quality of my learning at CSM was enhanced by my interactions with the *Connections* faculty.	12.5	4.2	83.3

Table 10. Survey responses from Connections *class entering in 1994.*

Question	Percentage of Student Responses		
	"Not at all" or "A little" (1) and (2)	Neutral (3)	"To some extent" or "To a great extent" (4) and (5)
Connections helped me discover and develop significant connections among my first year core subjects.	16.7	5.6	77.8
Connections helped me to enhance my critical thinking abilities and apply them in a variety of contexts.	5.6	22.2	72.2
Connections helped me to understand the historical and cultural contexts that have influenced developments in science, humanities, and engineering.	5.6	11.1	83.3
Connections helped me to become aware of and think about important historical and contemporary issues and ideas.	12.6	18.8	58.8
Connections helped me to further develop my sense of ethics and values, particularly about technology in the modern world.	22.3	16.7	61.1
Connections helped me to improve my oral and written communication skills.	11.2	16.7	72.2
I spent time outside of class socializing with members of my *Connections* group.	5.6	5.6	88.9
I spent time outside of class learning with members of my *Connections* group.	5.6	11.1	83.4
The quality of my learning at CSM was enhanced by my interactions with the other *Connections* students.	0.0	11.1	88.9
The quality of my learning at CSM was enhanced by my interactions with the *Connections* faculty.	0.0	0.0	100.0

Table 11. Survey responses from Connections *class entering in 1995.*

	1994-95 Class			1995-96 Class		
Question	Acad.	Social	General	Acad.	Social	General
What positive memories, if any, do you have of *Connections*?	1	19	1	0	15	0
What negative memories, if any, do you have of *Connections*?	7	3	8	3	2	3
What influence, if any, did the *Connections* program have on your educational experience at CSM or elsewhere?	8	8	3	3	7	4
What else would you like us to know about your *Connections* experience?	8	11	3	3	5	4

Table 12. Classification of anecdotal survey comments by Connections *students.*

These anecdotal comments allowed us to gain additional reflective insights about what the students truly valued in the program and what they thought was less important. Table 12 summarizes our classification of comments into three categories: 1) comments about academic topics, connections, projects, and/or the seminar, 2) comments about interactions with faculty or students or other social aspects about the program, 3) general comments about life at CSM or other aspects of the program such as the additional workload of the seminars and rigid scheduling (*Connections* students took all their classes together).

As Table 12 shows, students tended to reflect more about the social aspects of the program than the academic aspects. Nearly all the comments about positive memories of the program focused on developing friendships, study groups, and a support structure as the following example comments illustrate:

- "the close interaction with professors from a variety of departments and backgrounds"
- "the friendships made"
- "my best man and bride were *Connections* students"
- "great bond with students you have every class with"
- "the fond memories are of my time with *Connections* friends outside of class"
- "made it easier to get to know everyone and feel completely comfortable to ask questions or for help when needed"

D. Discussion: Connections *as a Learning Community*

Based on our analysis of the survey, we believe that a significant reason for the greater persistence rate of the *Connections* students was the learning community that they and the *Connections* faculty formed, especially in the second year of the program. Tinto [1] enumerates four outcomes associated with learning communities he studied, all of which were borne out in our study. First, students in learning communities "tended to form their own self- supporting groups, which extended beyond the classroom." We observed *Connections* students forming study groups and readily engaging in peer learning in our classes and seminars. At times, we formed the groups for specific tasks or projects, but student also chose to form their own groups that they tended to remain in for weeks or months.

Second, Tinto observed that "learning community students became more actively involved in classroom learning than other students, even after class.... They tended to learn and make friends at the same time." *Connections* students got to know their peers more quickly than typical first-year students and therefore became comfortable in active learning situations. Trust among students and *Connections* faculty was quickly established and remained strong throughout both pilot courses. In addition, many *Connections* students commented in the longitudinal survey about the life-long friendships they had begun while in *Connections* including two couples who eventually married.

Third, Tinto noted that "participation in the learning community seemed to enhance the quality of student learning." While *Connections* student grades were not significantly different than their comparison group peers, classroom sessions with *Connections* students often consisted of rich discussions about topics we had previously introduced in a module or during a seminar session. In addition, the retrospective survey indicated strongly that *Connections* students believed the program enhanced their intellectual experience.

Fourth, Tinto has reported that learning community students "persisted at a substantially higher rate than did comparative students in the traditional curriculum." *Connections* students persisted and ultimately graduated at rates approximately 25 percent higher than their comparison groups and CSM undergraduates as a whole. These differences came despite the fact that there was no special attention paid to *Connections* students after their freshman year. These results cannot be explained in terms of academic preparation as measured by SAT or ACT scores or academic performance as measured by grade point average.

V. Conclusion

Given the success of the *Connections* program in significantly improving the five-year graduation rate of "average" CSM students (those matriculating without the need to take remedial courses or opportunity to advance place), we believe that several lessons learned are relevant to improved student retention in engineering education. We believe that :

- Mentoring makes a difference. *Connections* students, particularly in the second pilot group, felt that interactions with faculty and peers were the single most positive aspect of their experience.
- Learning communities are important. Our experience strongly supports other studies that show students who feel that they belong from the beginning are more likely to persist, even if the intervention terminates.
- Content of integrated programs like *Connections*, while important, does not have the impact that personal contact has. We learned that our expectations and our students' expectations didn't necessarily match.
- Resources spent up front to allow top faculty to teach and mentor first-year students pay dividends in increased retention and overall satisfaction with the educational experience.

Based on our findings, CSM has increased the focus on learning community development and social support in the first-year success seminar required of all entering students and has experimented with the use of block scheduling so that groups of first-year students take at least 2–3 courses together. In addition, the concept of integrating the first year has been expanded as a result of a curriculum revision process that was informed by the *Connections* program. While these changes are not as focused (or resource intensive) as *Connections* was, modest increases in graduation rates of 5–7 percent have occurred in recent years that we believe can be at least partially attributed to them.

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