CAN SYSTEMIC CHANGE REALLY HELP ENGINEERING STUDENTS FROM UNDER-REPRESENTED GROUPS?

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Abstract *¾ In 1998-99 academic year, A&M completed the first phase in the transition from pilot curricula to new first and second year engineering curricula for every student. Inclusive Learning Communities (ILC) form the foundation for new curricula. At A&M, an ILC is a group of students, faculty and industry that have common interests and work as partners to improve the engineering educational experience. These communities value diversity, are accessible to all interested individuals, and bring real world situations into the engineering classroom. The key components of an ILC at A&M are: (1) clustering of students in common courses (math, engineering, science); (2) teaming; (3) active/cooperative learning; (4) industry involvement in the classroom; (5) technology-enhanced classrooms; (6) undergraduate peer teachers; (7) curriculum integration; (8) faculty team teaching; and (9) assessment and evaluation. Based on the experience with its pilot curricula and the experiences since institutionalization in 1998-99, A&M believes that the new curricula based on the ILC concept offer a superior educational experience for engineering students. To demonstrate this conclusion, quantitative data on retention and progress toward graduation will be offered for all male and female students, as well as minority and non-minority students.*

Index Terms ¾ Women, Minorities, Learning Community, Freshman Engineering, Retention.

INTRODUCTION

Alexander Meiklejohn originated the concept of learning communities when he created the Experimental College at the University of Wisconsin. Meiklejohn designed the Experimental College to provide a two-year, integrated foundation for liberal arts curricula. The Experimental College operated for two years between 1925-27. [1] The next major experiment in learning communities was initiated by Joseph Tussman at University of California Berkeley in the mid 1960s. [2] Interest and implementation of learning communities have grown during the 1990s as documented by the work by Gabelnick et. al. [3] and the National Learning Communities project. [4] Development of learning communities in both the first and second years of the engineering curricula at Texas A&M has been described in a paper by Fournier-Bonilla et. al. [5] The purpose of the present paper is to examine the impact of college-wide implementation of learning communities on the students and faculty at Texas A&M University.

COMPONENTS OF LEARNING COMMUNITIES IN ENGINEERING AT A&M

The new curricular model developed, in part, from the FC pilot curricula is based on Learning Communities (LC) theory. Broadly defined, a LC is a purposefully restructured curriculum and learning environment that link courses together. Linking provides for greater coherence in what students are learning, intentional interaction among students within an academic context, and greater interaction between faculty and students. Texas A&M added links to industry partners and labeled the *Inclusive Learning Communities*. There are nine components in the ILC model in the College of Engineering (COE) at A&M: (1) clustering of students in common courses (math, engineering, science); (2) using student teams inside and outside the classroom; (3) active/cooperative learning in the classroom; (4) industry involvement in the classroom; (5) technology enhanced classrooms; (6) undergraduate peer teachers; (7) curriculum integration between engineering, sciences (physics and chemistry) and mathematics; (8) faculty team teaching; and (9) assessment and evaluation. Brief descriptions of the implementation of these components are given below. A more detailed description of each of the nine components was presented in Caso et al. [6]

Clustering of Students

In the COE, ninety-six (96) students in each cluster enroll in common sections of their first-year science, engineering and mathematics courses. Faculty members teaching the clustered courses have a common set of students about whom they can share insights and assessments. Student teams assigned in the engineering course can be used in the

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mathematics and science courses. Engineering projects and other learning activities can be developed to reveal relevance and applications of concepts being studied in science and mathematics. Clusters provide an opportunity to integrate concepts across science, engineering and mathematics. In addition, they intentionally construct a social setting in an academic context in which students can talk to and work with each other on a common set of learning activities. This is an important element to the ILC model because it creates a classroom where the students get to know each other because they have the same peers in two or three courses. Astin[6] reports that the most important single issue in student persistence is a feeling of belonging.

Student Teams

There are several reasons for using student teams as an integral part of the ILC. First, employers are requesting engineering graduates with improved skills and more experience working within a team structure. Developing team skills while still in college increases students' potential for improved academic performance and simultaneously provides important skills to prepare them for the workplace. Second, engineering programs applying for accreditation under Engineering Criteria 2000 of the Accreditation Board of Engineering and Technology (ABET) are asked to demonstrate that their graduates have “an ability to function on multi-disciplinary teams.” [8] Finally, teams can provide social, emotional and academic support for their members. Interpersonal support is valuable for all students [9], but especially for women and underrepresented minorities.

The first-year engineering classes at A&M provide at least six hours of team training and many more hours of practical experience in teaming for the students. Students work on several projects in teams and faculty members base a portion of the grade on the assignments submitted as a team. Faculty members in the sophomore engineering classes also offer a large range of team learning experiences.

Active/Cooperative Learning

The COE has made a concerted effort to foster active and cooperative learning, for example, holding numerous workshops designed to assist faculty members incorporating active/cooperative learning into engineering learning communities. There are many definitions of both active learning and cooperative learning, but the TAMU model defines active learning as involving students in more activities (as opposed to listening), such as reading, discussing, writing, problem solving, and higher-order thinking skills including analysis, synthesis, evaluation. Cooperative learning consists of students working in structured groups that enhance their own and other’s learning. The work in the COE builds on numerous projects across the world that aim at demonstrating the efficacy of cooperative learning and illustrating how it may be integrated into the classroom.

Superior efficacy of cooperative learning approaches has been documented in a variety of studies. Hake [10], in a study of almost 6000 students in physics mechanics courses, shows that the use of interactive engagement (IE) results in higher conceptual gains, as measured by pre- and post scores on the Force Concept Inventory [11, 12] than traditional lectures. In fact, the smallest gains by students in IE classes were comparable with the largest gains by students in classes with traditional lectures. Felder, Felder and Dietz [13] compared outcomes for an experimental group to those for students in a traditionally-taught comparison group. The experimental group outperformed the comparison group on a number of measures

Industry Involvement

The COE established the following goals for the industry interaction: to show what engineers do; to demonstrate that engineers work in teams; to demonstrate the problem-solving process. The opportunity to learn from industry engineers and to experience how math, science, and engineering concepts go into solving real engineering problems increases understanding and connections between courses and career choice.

The COE uses three methods to build links between employers and students: 1) industry night discussions, 2) case studies, and 3) industry-sponsored workshops.

- **Industry Night Discussions –** Students in the second semester engineering course attend Industry Night Discussions. The purpose of Industry Night is to share information about a particular industry in an effort to educate students about different fields in engineering. The Industry Night presentations have multiple goals: 1) to excite the students about engineering; 2) to help them to make a commitment to engineering; 3) to provide engineering industrial information; 4) to talk about real world engineering problems; and 5) to provide information for students to aid in deciding majors.
- **Industry Case Studies -** Case studies are an effort to demonstrate "real world" engineering; that engineers work in teams; and to demonstrate the problem-solving process to currently enrolled engineering students. Companies usually send a team of 2-8 engineers who spend their day with students in an engineering course, typically a first semester, freshman engineering course. This team typically presents a 15-20 minute overview of a problem encountered in their company or industry. Students break into assigned teams, generate possible solutions to the problem, and then student teams present their solutions to the class. In the discussion that follows, the industry team presents the solution selected at their company and reviews the major contributing factors to the decision. In addition, the students are able to enter into a question and answer period with engineers from industry about their work environment, greatest challenges, rewards, etc. [14]

- **Industry-Sponsored Workshops** – When the ILCs were established for all entering engineering students, teaming was integrated into the classroom. Teaming was new for many of the faculty as well as most of the entering high school students. When team conflicts arose, faculty members were uncomfortable facilitating the student team conflicts. When the issue of conflict in teams was raised with industry members, they reported that similar issues arose in industry. They suggested that workshops on diversity or valuing differences had been helpful in the workplace and might help in the classroom. So, COE asked industry trainers to come to the college and offer the workshops to the first year students. The workshops are highly interactive and valued by student attendees. The college typically hosts up to 400-700 students each year.

Technology-enhanced Classrooms

Numerous people and groups have advocated the use of technology, particularly information technology, for improving engineering education. Improvements are wrought either by improving the efficiency with which students execute current tasks (e.g., using computers to symbolically or numerically solve an equation), or completely changing the way they approach design and analysis (e.g., designing a control system as a nonlinear optimization problem in the time domain instead of placing poles and zeros or shaping the frequency response).

Partner schools in the Foundation Coalition, including A&M, have concentrated on generative applications of technology. Each partner schools worked to create learning environments in which ubiquitous use of computers would be routine. Each institution built or remodeled classrooms so that students could use computers as a routine part of every class. At A&M, at least ten classrooms have been remodeled to provide one computer for every two students and to provide seating arrangements that facilitate the use of four-person student teams. Students use applications including Microsoft Excel, Maple, AutoCAD to gain facility in using these applications and to attack problems in science, engineering and mathematics. Using computer tools for routine manipulations and computations allow students to focus on tasks for formulating the problem and evaluating the quality of the results. Further, the first-year engineering courses are taught in two, two-hour blocks of time each week. Two-hour classes provide time for team-based learning activities that make use of the computers in the classroom. While the students are engaged in team exercises, the faculty members, the graduate teaching assistants and the undergraduate peer teachers are present to help the teams.

Undergraduate Peer Teachers

The goal of the peer teacher program is to create community and belonging for all the students in the section, especially those from underrepresented groups. These peer teachers also offered academic support in the evenings. The peer teachers are undergraduate students who had previously taken the ENGR 111/112 sequence. They are part of the teaching team that offers a section of either ENGR 111 or 112. The team consists of a faculty member who teaches the problem-solving and design components of the freshman engineering sequence, a faculty member who teaches the graphics components of the sequence, one graduate teaching assistant; and one undergraduate peer teacher. The peer teachers attend the engineering class; offer academic support two evenings a week on calculus, physics, chemistry and engineering; and serve as mentors and guides for the first year students in their particular cluster.

One of the issues brought out in research is the isolation experienced by many under represented students in engineering. The clusters help the students belong and feel a commitment to other students and faculty. Peer teachers have been instrumental in creating this sense of belonging. There is a positive, significant difference in how the students interact with the faculty and graduate teaching assistants, interacted with their team members, their study habits and in their confidence and determination to become an engineer.

Curriculum Integration

Another component of the ILC effort in the COE is attempts to help students link concepts from different elements. The value of helping students establish links is supported by research from several different disciplines. The A&M model builds connections between engineering, science, and math through closely aligning course topics and through the use of design projects. By integrating the topics from several subject areas in these projects the students are exposed to more complex and realistic problems. [15]

Faculty Team Teaching

There are several reasons team teaching is important to faculty and students in the new curricular model, among them: 1) the same learning theory that says teaming is good for students, transfers to faculty teaming; 2) the faculty team can model teaming to the students; 3) it makes the classroom less dependent on an individual faculty member; and 4) a team of faculty provide students with more than one personality to which they can relate.

Student-faculty interaction was enhanced by use of teaching teams consisting of a problem solving faculty, a graphics faculty, a graduate teaching assistant, and an undergraduate peer teacher. With an instruction team of four in a class of 100, the student-instructor ratio was only 25:1. Use of instruction teams required coordination and communications not necessary in single instructor courses. However, the extra work required was not substantial and the overall benefits to the classroom environment were substantially more than the cost.

Assessment and Evaluation

Continuous improvement and data driven decisions are the goal of the assessment and evaluation plan. Faculty members know that evaluation must be comprehensive, on going, and support the goals of the program. This assessment also helped provide information to make the extensive change necessary to bring the FC pilot into existence for all the first year students. For example, the decision to expand and incorporate peer teachers into the ILC model was a result of faculty and student evaluations after a two semester pilot program. Comparative GPA analysis also was considered. Another example where assessment encouraged the college to change was the student comments about industry case studies. Students were asked, on an evaluation form, what else the college could do to enrich their first year experience. By far, most students requested more opportunities to visit with industry engineers. Based on their feedback, the college expanded the case studies to both semesters (ENGR 111 and 112), and began the Industry Night program. Finally, the diversity workshops were a result of faculty conversations about what was working in the classroom and where their frustrations lay. Conflict within the teams was mentioned many times. So, diversity workshops were solicited from industry. These examples illustrate how assessment, evaluation and feedback have improved the ILC model.

QUANTITATIVE DATA COMPARING WOMEN AND MEN IN LEARNING COMMUNITIES

Since 1998-99, learning communities are offered to all of the entering engineering majors. For first-time first-year students may be placed into one of five categories.

1. Students who participated in learning communities for two semesters. These are students who enrolled in sections of the ENGR 111/112 (Foundations of Engineering I/II) that are clustered with calculus and/or physics classes. In analyzing student performance it is important to understand that in order to participate in a learning community for both Fall and Spring semesters, students must successfully complete each of the clustered classes in the Fall Semester.
2. Students who never participated in learning communities, but successfully completed all of the science, mathematics and engineering classes that are a part of their Fall semester engineering curriculum. In terms of course experiences, students in this category should be roughly comparable to students in the first category.
3. Students who participated in a learning community during the Fall semester, but did not successfully complete one or more of their courses in the Fall semester cluster so they would have been ineligible to participate in a learning community during Spring semester.
4. Students who never participated in the learning communities, but **also** did not successfully complete all of the science, mathematics and engineering classes that are a part of the Fall semester engineering curriculum.
5. Students who participated in a learning community in the Fall semester and successfully completed all of their Fall semester courses, **but** did not participate in a learning community in the Spring semester.

In comparing the effect of learning communities, only the the first two groups are comparable in terms of their course experiences and the following analysis will focus on these two groups. (Additional data for all five groups may in found in Caso et. al. [6])

The first measure on which the two groups will be compared is retention. Tables 1, and 2 show retention after two years for the 1998 and 1999 cohorts. Table 3 includes 2000.

Table 1. Comparison of Second-Year Retention between LC2 and Non-LC2 Students by gender

Cohort	Category*	Men	Women
1998	LC2	87.0%	80.9%
	Non-LC2	75.0%	69.6%
1999	LC2	85.4%	79.4%
	Non-LC2	66.7%	66.7%

* LC2 = students participating in ILCs for both semesters of the freshman year, Non-LC2 = students not participating in ILCs for either semester of the freshman year

Table 2. Comparison of Second-Year Retention between LC2 and Non-LC2 Students by minority status

Cohort	Category*	Majority	Minority
1998	LC2	85.0%	92.0%
	Non-LC2	74.0%	70.0%
1999	LC2	84.2%	86.2%
	Non-LC2	75.0%	40.0%

* see table 1 note

Table 3. Comparison of Retention between LC2 and Non-LC2 Students

Cohort	Category*	First-Year Retention Percentage	Second-Year Retention Percentage
1998	LC2	90.70%	85.70%
	Non-LC2	84.20%	73.70%
1999	LC2	92.90%	84.40%
	Non-LC2	83.00%	72.30%
2000	LC2	93.40%	-
	Non-LC2	97.90%	-

* see table 1 note

For both the 1998 and 1999 cohorts, significantly more of the male students, female students, majority students, and minority students who did participate in two ILCs were retained than were those who did not participate in learning communities. Table 3 shows the opposite trend is true for first-year retention of the 2000 cohort; however, both retention rates are very high.

Another measure on which the first (2ILCs) and second (non-ILC) categories can be compared is time that it takes to be ready to enter the sophomore year (catalog) courses. Engineering students at A&M enter the college as first-year students, but do not enter a department until they have completed a set of courses know as the Core Body of Knowledge (CBK). CBK courses include courses in calculus, physics, chemistry, engineering, and English. The time required to complete the CBK courses is an indicator of how rapidly students complete their engineering degrees.

Table 4 displays the time required to complete the CBK courses. At every time interval after starting the first year a higher percentage of students who have participated in inclusive learning communities are prepared to enter the sophomore year than students who did not participate in learning communities. Both male and female students show similar advantages. Similar advantages are seen for minority students. These advantages in terms of time to enter the sophomore year exist despite the fact that students in the Non-LC2 earned higher grades than students in the LC2 category, although the grade differences are small.

Table 4. Comparison of time to complete CBK courses between LC2 and Non-LC2 Students

Cohort	Semesters	LC2*		Non-LC2*	
		men	women	men	women
1998	2	54%	59%	40%	48%
	3	21%	15%	17%	9%
	4	8%	7%	10%	9%
	5	2%	0%	6%	4%
1999	2	43%	57%	38%	38%
	3	24%	19%	14%	14%
	4	9%	9%	10%	10%

* see table 1 note

Each student elects whether to participate in a learning community; however, the choice is whether to participate in clustered or non-clustered sections of courses since the other eight components of learning communities are also presented in the non-clustered sections. Choice of sections is based on more than clustered vs. non-clustered, e.g., for example, times at which classes are offered and availability of sections; therefore, any effect of volunteer selection is likely to be small.

QUALITATIVE DATA ON STUDENT EXPERIENCES IN LEARNING COMMUNITIES

A recent qualitative study of the experience of inclusive learning communities in five of the six member institutions of the Foundation Coalition [7] showed the value of this concept on several levels. The impact on student learning was especially dramatic. Students spoke at length about learning to work in teams, and they valued this experience highly in spite of difficulties they encountered in working together. They also talked about learning how they learn best, which for everyone was a discovery process, though most agreed that memorization was no longer sufficient and that application of concepts was essential. Especially significant was the extent to which they learned to use one another as resources. When they needed help learning difficult material, their typical pattern was to turn first to their team members or to other students in their cohort. If that didn't work, they would seek out a TA or tutor; the professor was usually approached last. Other students were effective teachers, they were readily available, and there was less risk—as one student said, "[You] *are definitely more willing to ask a dumb question to someone your own age* [rather] *than to a professor*". They also spoke about the value of the learning itself: "*Sometimes reading the book, it doesn't sink in. Asking your prof, it doesn't sink in. Sometimes just one of your peers explaining it to you and you get it, maybe because they're on your level*". The professors understood this and one summarized the situation well:

> *"The peer teacher probably was the most successful way of reaching the students, in my opinion. I hold office hours, but very rarely do students come. I don't fully know why; I don't think I'm an intimidating person. Maybe they see that since I'm a grade-giver that if they express their ignorance that I will remember and so they tend not to want to come to me for help. But they seem very willing to go to a student of their own age, even more so than a graduate student. So what Julie, the peer teacher, did was she would hold help sessions twice a week…typically for an hour or maybe an hour and a half. And students, maybe 20 or 30 students would come to the sessions out of 100….Judging from her comments and the students' comments, it seemed to be a very effective way to help students."*

The students described two different types of learning. First, they learn how to survive in college, and central to that is developing self-discipline and time-management skills. The second type of learning is conceptual, what several students called learning "*to think like engineers*." It is clear that thinking like an engineer involves understanding how things work, developing skills of critical analysis, and applying all this to solve problems in multiple ways.

The other major benefit of inclusive learning communities that this study found was the social support that students had from one another. They valued the cohort structure because it enabled them to make friends easily, and this provided the support they needed to make it through the program. As one student said, "*Instead of just me against the world, it's like me and my twenty friends against the world! Together we stand, divided we fall*". By having two or three courses with the same group, they create for themselves a significant support group. Because their numbers are still small, this benefit is less dramatic for women and minority students. While they too reported social benefits from being in a cohort, the women reported a significant amount of gender discrimination. A common way many of the women coped with this discrimination was to continually prove themselves. One woman described this well:

> *"In the beginning I felt like you have to kind of prove yourself, because in my group, anything I said, the guys were like "That's not efficient," or "We're going to go with this idea." And I was just like, "What?" And then my professor would say something just like what I had said, and they would just dismiss it. But then after that first round of tests, when I kicked their butts, then they started listening to me. After that, everything was OK. But you kind of have to show them what you're made of."*

The downside of this strategy, however, is that the women students are less free to ask questions because doing so meant they risked being labeled "*the dumb girl*."

CONCLUSIONS

Development and implementation of learning communities in the Dwight Look College of Engineering at Texas A&M University has drawn on an enormous breadth of learning theory and practical pedagogical practice, including four years of a pilot curriculum initiated under the auspices of the Foundation Coalition. Many of the components of the learning communities theoretically should have positive impact on learning and learning experiences for students, especially women and minorities. Both quantitative data and qualitative data indicate positive impact on student retention, student progress, and student learning, both for all students who participate in learning communities and under represented engineering students. However, challenges in improving the learning environments for under represented students remain. The most crucial challenge is changing attitudes and behavior of male students toward women. For faculty members, the most pressing challenge is balancing potential benefits of tighter integration between classes with the costs, particularly time, associated with tighter integration. Hopefully, this paper has provided valuable information for others considering implementation of learning communities.

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