Engineering Learning Communities

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Engineering Learning Communities: Implementation and Results

Abstract
Learning communities are used widely across the country as a means of increasing retention of first year students at the university level. Living learning communities where students of the same major reside in a common residential hall of university campuses are common in engineering programs around the nation and their results are prevalent in the literature. In fall 2007 West Texas A&M University, a regional institution of 8000 students in the Texas Panhandle, began offering curricular learning communities for first year engineering majors. This type of learning community model enrolls a cohort of students into two or more courses linked by a common theme. The goal of this program was to create a community among the first year engineering students, and instigate study groups early in their academic career which would offer support through the gateway mathematics, science and engineering courses. Engineering learning communities initially were created linking *Precalculus* and *Fundamentals of Engineering* or *Calculus I* and *Fundamentals of Engineering* for first semester freshman engineering majors. By student request the experiences were expanded in 2010 to a second semester sequence linking *Calculus II* and *Engineering Statics*.

Propensity score analysis was used to evaluate the impact of the Engineering Learning Communities on first year retention of students in the engineering program and at the university. The method of propensity scores was used to obtain a matched comparison group from historical and concurrently enrolled first year engineering majors. The covariates of interest were: full-time or part-time status, sex, first generation status, age, ACT composite score, transfer or native student, and socio-economic status. Rate of retention was then compared for those enrolled in the learning community versus the matched control group. First year engineering majors who participated in a learning community were retained in engineering at a rate of 53% in comparison to 46% for those not enrolled in the learning community. Although not statistically significant ($p=0.0924$), after matching on the propensity score students enrolled in the engineering community were retained in engineering and at the university at a higher rate than those not enrolled in the learning community experience.

Introduction

Across the United States, institutions of higher education have utilized varying forms of a learning community experience in efforts to improve outcomes for first-year students. Lenning and Ebbers [1] defined four common forms of learning communities: (1) curricular learning communities that enroll a cohort of students in two or more common courses; (2) classroom learning communities where a cohort of students enrolled in a large lecture are broken into smaller cohorts for cooperative learning and group process learning opportunities (3) residential living and learning communities where students with a common major live in the same area of a residential hall increasing the opportunity for out-of-class learning experiences; (4) student type learning communities which enroll a targeted group, for example academically at risk students, honors students or minorities in engineering. While living and learning residential hall programs are fairly common in engineering programs across the country, curricular learning communities are rare in the engineering curriculum [2]. In fall 2007, the disciplines of engineering and mathematics at West Texas A&M University (WTAMU) began offering curricular learning communities for first-year engineering majors. Initially two learning communities were created which dual enrolled students in a common section of *Fundamentals of Engineering* and a freshman level mathematics course. In spring 2010, the program expanded to offer a follow-up learning community experience with dual enrollment in *Calculus II* and *Engineering Statics*.

This paper describes the structure of the learning community courses in detail. A preliminary statistical analysis is presented which utilizes propensity scores to examine the impact of the learning community experience on first-year retention in engineering and at the university. The results of this analysis, limitations and conclusions are discussed.

Engineering Learning Community Design

Several published studies have linked learning communities to increased retention of first-year students, higher first year GPAs, and lower incidence of academic probation [3]. Zhao and Kuh [4] indicate the cluster enrollment model featuring a cohort of students co-enrolled in two or more courses is improved upon when the faculty involved in these courses design activities that incorporate the curriculum of the courses in cluster. This integrated curricular approach was the basis for the WTAMU engineering learning community model. The goal was to increase first-year retention of engineering majors by (1) creating a community of learners that would form study groups early in their academic career; and (2) integrating the foundation disciplines of mathematics and physics into practical engineering applications using Problem-Based Learning in order to increase student engagement [5-9]. This model for learning communities in engineering promotes the development of social communities among engineering majors as well as aids students in building connections between the prominent disciplines in engineering education [10].

Two learning communities were originally created in fall 2007 linking sections of *Precalculus* and *Calculus I* to distinct sections of the first year engineering course, *Fundamentals of Engineering*. These were termed the Precalculus and Calculus learning communities. Upon student request, in spring 2009, a follow-up learning community was created linking *Calculus II* and *Engineering Statics*. In all cases the courses were linked, requiring enrollment in both classes, by the WTAMU Office of the Registrar. Any student attempting to register for a course section clustered in the learning community was notified of mandatory registration in the second course. Prior to the first class day personnel from the WTAMU First Year Experience Program verified course rosters to insure all students enrolled in the learning community were registered for both the mathematics and engineering course. Any students found to not be enrolled in both courses were contacted to either change sections or enroll in both courses.

Student feedback from early learning community experiences indicated the importance of informing students upon registration, the first class day and throughout the semester, of the purpose of the learning community experience. Students understanding the goals of the program helped in promoting a collaborative and purposeful atmosphere throughout the semester. The engineering and mathematics courses are taught by a member of the respective faculties; however, the course instructors work closely prior to the beginning of the semester and throughout the semester to integrate the content of the two courses whenever possible. It is simply not feasible to constantly integrate course material in a learning community as each course has its own objectives, but with curriculum flexibility and careful planning, faculty have been able to integrate the courses with consistent periodic activities and projects throughout the semester. Our experience indicates the more consistent the integration, particularly in the first semester courses, the more likely the students are to be engaged in the community. Problems taken from *Introductory Mathematics for Engineering Applications* developed by Wright State University are used in both the Precalculus and Calculus courses of the learning community as a means to link mathematics concepts to engineering applications [11]. Problem-based learning project activities are used extensively as group projects to cultivate student interaction and develop interdisciplinary problem solving skills. See [5, 12, 13] for the details of these projects and their integration into the learning community curriculum. Learning community instructors indicate the key elements to success of this model are:

- Emphasis to the students the goals of the learning community initially and throughout the semester
- Consistent integration of the mathematics and engineering course curriculum throughout the semester
- Implementation of Problem-based learning projects in both course allowing students to apply theoretical engineering and mathematics principles in the solution of significant problems
- Frequent communication between the mathematics and engineering learning community instructors, and this communication evident to the students, indicates faculty involvement in the learning community.

Traditional stand alone sections of the mathematics and engineering courses offered in the learning community format were offered simultaneously to the engineering learning communities each semester. These courses were traditional lecture-based courses in *Precalculus*, *Calculus I* and *Calculus II* taught by mathematics faculty and courses in *Engineering Fundamentals* and *Engineering Statics* offered by faculty in engineering. The traditional courses in mathematics are populated by students enrolled in a variety of STEM fields, including engineering. No problem-based learning or other integrated curriculum methods are utilized in these courses due to the diversity of the student majors.

Early assessment of the engineering learning communities exhibited consistent and higher pass rates in *Calculus I*, *Calculus II*, and *Engineering Statics* courses. Student surveys in first year engineering courses both traditional and from the learning communities showed a higher percentage of students in the learning community indicating their intent to persist in the engineering degree field. This and additional survey results are indicated in Table 1 below. Retention rates to the second year were higher in all cases for students enrolled in the learning communities compared to those choosing not to enroll. However, participants are choosing individually at this level to enroll in a learning community experience. Are these students naturally more motivated to persist in engineering then those who chose not to enroll? ACT and SAT scores for students in the learning community were in most years slightly higher than those not in the learning community. A larger proportion of students not enrolled in the learning community were first-generation students. These issues confounded the seemingly positive results of higher pass rates and retention rates indicated in a simple annual analysis. This paper presents the initial results of a formal statistical analysis that allows for control of the student confounding variables.

Table 1: Sample survey results of student impressions of learning gains in *Engineering Fundamentals*

Survey Question	Learning Community % Agree or Strongly Agree (N=125)	Traditional % Agree or Strongly Agree (N=368)
I plan to complete a degree in engineering.	92%	84%
ENGR 1201 has added to my skills in working on a team.	93%	63%
ENGR 1201 has added to my skills in identifying and formulating an engineering problem.	85%	45%
ENGR 1201 has added to my skills in applying engineering principles.	80%	32%
ENGR 1201 has improved my critical thinking skills.	66%	30%
ENGR 1201 has improved my understanding of the relationships between engineering concepts.	87%	27%
ENGR 1201 has improved my ability to use math to solve problems.	92%	37%

Research Questions

Our interest in analyzing the results of the engineering learning community stemmed from two sources. First, the engineering learning community was initiated by faculty in mathematics and engineering interested in improving the retention of first year engineering majors and was funded by the National Science Foundation through the Science, Technology and Engineering Talent Expansion Program. Second, the engineering learning community was one of several learning community experiences considered a part of the university Quality Expansion Plan for university accreditation. The university's goal was to increase first year retention across the university through these experiences. The engineering learning community is the only learning community of those originally offered as part of this accreditation plan that has been sustained since their origin. These two joint initiatives devised our research questions in this observational study.

- Does participation in the engineering learning community improve retention to the second year in engineering?
- Does participation in the engineering learning community improve retention of engineering majors at the university?

Setting and Subject Pool

West Texas A&M University (WTAMU) is a regional institution located in the Texas Panhandle with an enrollment of 8000 students. The region is largely low income and only 18% of the Panhandle population over the age of 25 has a bachelor's degree. Almost 65% of WTAMU students are from the Panhandle area. Consistently over 50% of the WTAMU student population is first generation college students. Three regional community colleges are located within 50 miles of the university contributing to a population of WTAMU engineering majors that is over 30% community college transfers. Demographically WTAMU is 67% Caucasian, 22% Hispanic, and 5% African American. In engineering, since 2005, the engineering student population has been over 25% Hispanic.

Data and Methodology

In order to address the complications presented in analyzing student retention with students self-selecting into the experimental group, Propensity Score analysis was used to develop an evaluation group for comparison of first year retention rates of engineering students in the learning community.

A propensity score is the conditional probability of assignment to a particular treatment, in this case, a learning community, given a vector of observed covariates. Due to the dichotomous nature of enrolling in a learning community or not, propensity scores are commonly calculated from a logistic regression model. Using "enrollment in the learning community" as the outcome variable and the vector of observed covariates, a logistic regression model is developed that measures a student's "propensity" or likelihood of enrolling in the learning community treatment. Students from the experimental learning community cohort are then matched with a student in the non-learning community control group using nearest neighbor matching without replacement. This method of matching identifies the control group unit with the closest propensity score to the first individual in the learning community and then removes the pair from both groups. The next experimental unit is then matched with the control unit with the closest propensity score and again both are removed from the groups. This method continues until all experimental units have been matched with a unit from the control group. Once a suitable control group is obtained, the rate of retention to the second year for the experimental learning community cohort and the matched sample from the control population are compared [14-16].

The WTAMU Office of Institutional Research collected data on all science, technology, engineering and mathematics (STEM) majors enrolled in *Precalculus* or *Calculus I* as their first math course at WTAMU or *Calculus II* from spring 2003 through spring 2011. *Calculus I or Precalculus* initial course enrollment was chosen to generate the sample so that the comparison pool of students entered WTAMU at the same mathematics level as those in the learning community and would be enrolled in the same mathematics courses in the first year. Ideally the sample population of the engineering learning community would be compared to a population of concurrent and historical engineering majors at WTAMU; however, the WTAMU engineering program began offering its first degree program in mechanical engineering in only 2003. The program in its first five years enrolled primarily white male returning students.   The student population of the current engineering program is dramatically more diverse, with a population that is evenly divided between first time freshmen, returning students and community college transfers. In addition, the program enrollment is almost 10% female and over 25% minority students.

The enrollment of the engineering learning community is over 50% first time freshmen, which was only a small percentage of the historical engineering population at WTAMU. The rapid change in the diversity of the engineering program and type of students enrolled may hinder the nearest neighbor matching strategy from finding a suitably matched control group within the historical and concurrent engineering major population. An additional student control cohort exists when considering all STEM majors at WTAMU. The larger total STEM cohort is a more diverse student sample from which to compare and yet these students have similar academic pathways to engineering majors in the first year. Our analysis will therefore utilize both an engineering major control group and a STEM major control group while assessing the impact of the learning community on first year retention. We define the Engineering Control Group as students majoring in an engineering field and enrolling in their first Precalculus or calculus course from fall 2003 to fall 2010; and the STEM Control Group as students majoring in any STEM field who enrolled in Precalculus or a calculus course from fall 2003 through fall 2010. Table 1 displays a comparison of significant variables for each control group versus the experimental engineering learning community.

Table 2: Comparison of Experimental, Engineering, and STEM control group characteristics

Experimental and Control Group Comparison of Significant Variables for Logistic Propensity Score Model			
Variable	ENGR LC N=193	ENGR Control N=270	STEM Control N=607
Age (Mean)	18.6	19.5	19.8
HS Rank (Mean)	66	65	58.7
Student Athlete (Count)	25	48	90
First-time Freshman Enrollment (Count)	117	85	179
Returning Student (Count)	74	179	414
Gender (Count of Females)	30	35	195

Beginning with the engineering control group, in order to construct the logistic regression model which will model the likelihood a student enrolls in the learning community experience based on demographic and academic characteristics, data from students enrolled in the learning community and those found in the engineering control group are combined to form a single dataset. The students' learning community status (in a learning community or not) is then regressed against variables of interest using a binary logistic regression model. The resulting model is used to calculate a propensity score for each observation in the experimental learning community and engineering control group. The propensity score model for the STEM is constructed similarly.

The complete list of variables considered to develop the logistic models were: full or part-time status, gender, first generation college student status, age of student during the semester in initial math course (*Precalculus*, *Calculus I*, *Calculus II*), size of high school attended, graduating high school rank, ACT composite score, ethnicity, transfer or native student, student athlete status, and low income status (determined by Pell Grant eligibility). Variables were entered into the logistic regression model using a step-wise process. Variables of ethnicity, high school size, and full or part-time status were removed from the models due to separation of variables, indicating the values of these variables were completely separated into the learning community or control group. The final logistic regression model for both control groups determining the propensity to enroll in a learning community included the following covariates: Student athlete status, high school graduation rank, student type (transfer, returning or first-time freshman) age, and gender. Once each observation was assigned a propensity score, nearest neighbor matching without replacement was used to match each observation in a learning community with an observation in the control group. Retention rates were then compared for observations of engineering majors enrolled in the learning community versus students not enrolled in the learning community using both engineering majors and STEM majors as a control.

Results

Table 3 displays first year retention results in engineering and at the university for students enrolled in the engineering learning community versus both the engineering control group. After matching engineering students in the learning community to historic and concurrently enrolled engineering majors of the same level using propensity scores with nearest neighbor matching, 52.85% of students enrolled in the learning community were retained to the 2nd year as compared to 46.11% of those not enrolled in the learning community. Using a normal test for proportions, this difference of 6.74% was not statistically significant at a 5% level (p=0.0924). A 95% confidence interval for the difference in first retention rates of engineers in the learning versus those not in the learning community was found to be (-0.0322, .1669). An odds ratio estimate indicates a student in the learning community is 1.3 times more likely to be retained to the second year than a student not in the learning community with a 95% confidence interval of (0.8780, 1.9539).

Table 3. Results of first year retention comparisons versus engineering control group

Retention in Engineering	Engineering LC (N=193)	Engineering Control (N=270)
Retention to 2nd Year in Engineering	52.9%	46.1% (p=0.0924)
Retention to 2nd Year at University	75.1%	68.4% (p=.0702)

A second analysis was performed to investigate retention at the university of engineering majors in the learning community versus those not in the learning community. Analysis shows 75.13% of students enrolled in the learning community were retained at WTAMU to the second year as compared to 68.39% in the matched comparison group. This difference of 6.74% was not statistically significant (p=0.0702). The 95% confidence interval for the difference in retention was found to be (-0.0222, 0.1569). Utilizing the odds ratio estimate, a student in the learning community was 1.4 times as likely to be retained at WTAMU as an engineering major not in the learning community, with a 95% confidence interval of (0.8940, 2.1799).

The population of STEM majors at WTAMU both historic and concurrent to the learning community whose academic career was initiated at the same mathematics level provided a larger and more diverse sample for matching purposes. When retention in a STEM major is compared for those in the learning community versus the STEM control group, 52.9% of those enrolled in the learning community were retained in their major as compared to 40.7% of matched STEM majors. This difference was found to be statistically significant (p=0.0014). A 95% confidence interval for the difference in first year retention rates in the STEM major was calculated to be (0.0536, 0.2205). An odds ratio estimate indicates students in the learning community were 1.74 times more likely to be retained in their major than those in the control group with a 95% confidence interval of (1.23, 2.44).

When university retention is examined for these two groups, 76.3% of students in the learning community were retained to the university as compared to 70.37% of the STEM control group. This difference was not statistically significant at a 5% level (p=0.0593). The 95% confidence interval for the difference is (-0.0152, 0.1337). The odds ratio estimate indicates students in the learning community were 1.36 times more likely to be retained at WTAMU than those in the control group. The confidence interval for this ratio was (0.9238, 1.9883). Table 4 summarizes these results.

Table 4. Results of first year retention comparisons versus STEM control group

Retention in STEM	Engineering LC (N=193)	STEM Control (N=607)
Retention to 2nd Year in STEM major	52.9%	40.7 (p=0.0014)
Retention to 2nd Year at University	76.3%	70.4% (p=0.0593)

Conclusions and Future Analysis

The analysis presented in this paper on the impact of first year engineering learning communities on student retention accounts for the self-selection bias present in these type of educational interventions. Although they are inconclusive, the results are promising for a significant impact and clearly point to future directions for our continued analysis. The nearest neighbor matching (without replacement) technique has inherent challenges produced by matching each experimental unit with the best remaining unit in the control group. Nearest neighbor is one of three prominent methods in the literature each with its own challenges. Our current direction for further investigation is to apply alternative matching strategies of Radius, Kernel, and Stratification to find the matching strategies that produce similar results [17]. Further investigation with subpopulations will be conducted using greedy matching strategies which allows the matching of experimental and control units by a specified covariate such as race or first-time in college status [18].

In all presented comparisons, retention rates of first year engineering majors were higher than the statistically matched comparison group both in engineering and at the university. A significant impact on retention is found when engineering majors in the learning community are compared with the population of all STEM majors with a similar mathematics pathway in the first year. However, all results presented are statistically significant at the 10% level. This level of evidence has been sufficient for institutionalization and expansion of learning communities at West Texas A&M. The program can be offered with no additional costs to the university, as all sections of mathematics and engineering courses each semester would have been offered with or without the learning community program. The learning community simply encouraged students to dual enroll in two courses in order to create a community of learners that will hopefully sustain them to graduation.

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Acknowledgements

The authors would like to thank the National Science Foundation, *DUE 0622442*, for funding to support this program