
AC 2011-340: ENGINEERING LEARNING COMMUNITIES: RELATIONSHIPS, RESULTS, AND RETENTION

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Engineering Learning Communities: Relationships, Results, and Retention

Abstract

Learning communities that dual enroll students in a block of two or more common courses have been implemented across the country in a variety of disciplines and first-year experience programs as a means of increasing retention of first-year students. However, these curricular adaptations are not commonly found in engineering programs. Since fall 2007, engineering and mathematics faculty at West Texas A&M University (WTAMU) have worked in coordination with the WTAMU Office of First-Year Experience to offer engineering learning communities that dual enroll first-year engineering students into a section of *Fundamentals of Engineering* and a freshman level mathematics course, either Pre-Calculus or Calculus I. In spring 2010, this program expanded to offer a learning community linking Calculus II and Engineering Statics. This engineering learning community model integrates the curriculum of mathematics and engineering and through Problem-Based Learning (PBL) experiences provide real world application for the students. Students enrolled in the learning community have shown a higher rate of success in the learning community mathematics courses and through surveys and focus groups have indicated a stronger intent to persist in the engineering field and student impressions of larger gains in engineering problem solving skills than first year engineering students not enrolled in the learning community.

Introduction

Learning communities have been implemented across the country in a variety of disciplines and first-year experience programs as a means of increasing retention of first-year students. Learning communities have varying forms, however Lenning and Ebbers [1] have identified 4 common forms (1) curricular learning communities that enroll a cohort of students in two or more common courses paired or clustered 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. Several published studies have linked learning communities to increased retention of first-year students, higher first year GPAs, and lower incidence of academic probation. [2-4] Zhao and Kuh [5] indicate the simple cluster enrollment model of a cohort of students co-enrolled in two or more courses is improved upon when the faculty involved in these courses design activities that require the application of topics from the other course. This curriculum integrated approach to learning communities promotes the development of critical thinking skills and an interdisciplinary approach to problem solution. 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. [6] Since fall 2007, engineering and mathematics faculty at West Texas A&M University have worked with the coordination with the Office of First-Year Experience and to offer engineering learning communities that dual enroll first-year engineering students into a section of *Fundamentals of*

Engineering and a freshman level mathematics course, either Pre-Calculus or Calculus I. In spring 2010, this program expanded to offer a learning community linking Calculus II and Engineering Statics. The engineering learning community model follows the learning community model of dual enrolling a cohort of freshmen engineering students into common sections of an engineering and mathematics course while also integrating the curriculum of these courses through regular assignments that utilize the content of both courses and Problem-Based Learning projects which apply theory to real-world problems.

The WTAMU Model for Engineering Learning Communities

West Texas A&M University (WTAMU) began its engineering learning community program in fall 2007 through funding provided by the National Science Foundation Science Technology Engineering and Mathematics Talent Expansion program. The goal of this program was to increase retention of first year engineering majors by (1) creating a community of learners that would form study groups early in their academic career; and (2) integrating of the foundation disciplines of mathematics and physics into practical engineering applications using Problem-Based Learning in order to increase student engagement [7-11].

Two learning communities were initiated linking the course of *Fundamentals of Engineering*, ENGR 1201, with two freshman mathematics courses, *Pre-calculus*, MATH 2412, and *Calculus I*, MATH 2413. Student eligibility for each learning community was based on their ACT/SAT based mathematics placement. A student enrolling in either learning community was required to dual enroll in the linked section of the mathematics and engineering courses so that the learning community cohort of students would attend their mathematics and engineering courses with the same group of students. Based on the success of the learning community linking Calculus I to Fundamentals of Engineering, a third learning community was added in spring 2010 linking Calculus II and Engineering Statics.

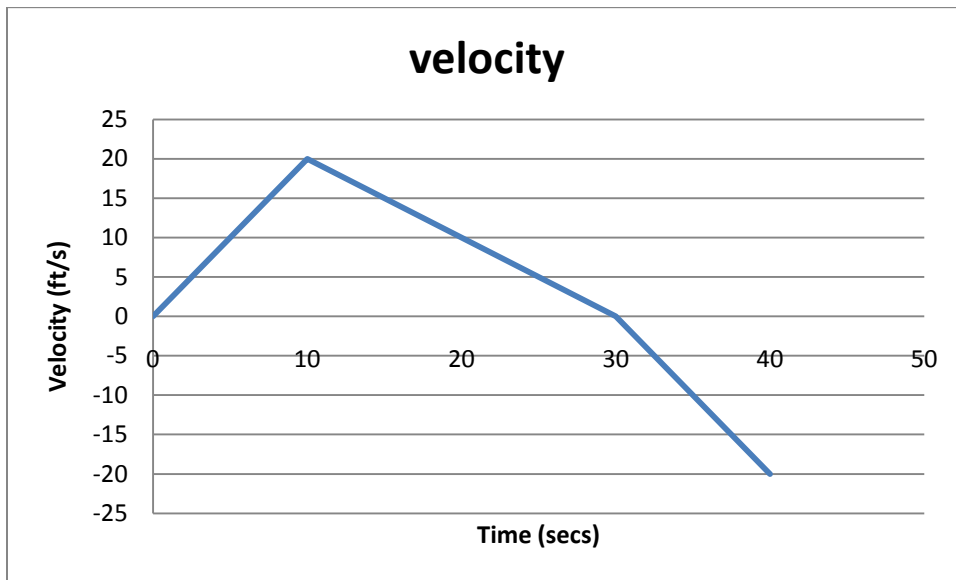
The model for these engineering learning communities has focused on a co-curricular approach. Although a member of the mathematics faculty served as the instructor on the mathematics course and an engineering faculty member taught the engineering course, these faculty members worked closely to integrate the content of the two courses. This program has experienced dramatic successes and some failures; however both have provided lessons well learned that have contributed to the model the university is expanding upon today.

Key elements of the WTAMU Engineering Learning Community model are:

- Emphasis to the students of 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 PBL projects in both course allowing students to apply theoretical engineering and mathematics principles in the solution of a significant problem
- Frequent communication between the instructors regarding the status and attitudes of the students in the learning community

Mathematics faculty feel the key to the success of this program is the consistent integration of engineering applications into the Pre-calculus and Calculus curriculum. When possible, a new mathematics concept is introduced in the context of an engineering application. The similar applications are assigned as additional homework problems. For example when introducing the concept of the derivative, the following problem was introduced.

The velocity of a vehicle starting from rest at position $x=0$ is shown in the figure below:



Knowing that acceleration is the rate of change of velocity, sketch a graph of the acceleration curve.

When introducing integration the same problem was used with the following question:

Knowing that velocity is the rate of change of position $x(t)$, if the maximum position is 100 feet and the final position is 20 feet, sketch the graph of the position function $x(t)$. [12]

The introduction of a new topic has also been used as the startup of a PBL project. Introducing the project before covering the content allows students to hypothesize a solution and then build on that hypothesis as student knowledge of the content expands. Optimization in Calculus I has been introduced through a PBL project where students optimize the cost of laying an oil pipeline around or through a swamp. A map and scale is given indicating where the pipeline originates and must end. The costs of laying the pipeline through the swamp and on dry land are given per unit foot and student must write the equation for the cost as a function of the path chosen. Engineering faculty chose this problem because of its emphasis in modeling and design. No information is given to the students regarding an appropriate shape to model the swamp. Students must determine a shape that will have a mathematical solution and yet accuracy must also be considered. [13]

Results

The most notable success of the engineering learning community model is the increase in successful completion rate for Calculus I when compared to previous courses with the same instructor as well as current calculus students not enrolled in the learning community. The calculus learning community has shown a consistent 75 to 80 percent pass rate for the students since its inception.

Surveys were administered to all students enrolled in *Fundamentals of Engineering*, including linked and non-linked sections at the conclusion of the fall 2008 and fall 2009 semesters. Some key findings were:

- When students were asked if *they planned to complete a degree in engineering*, 16% of freshmen engineering students not enrolled in a learning community either agreed or strongly agreed with the statement as compared to 8% for those in the learning communities.
- When asked how much the ENGR 1201 course had added to their skills involving *working on a team*, 63% of those not enrolled in the learning community responded either “a great deal” or “a lot” as compared to 93% for those enrolled in the learning community.
- When asked how much the ENGR 1201 course added to their skills in *identifying and formulating an engineering problem*, 85% of those in the learning community responded either “a great deal” or “a lot” as compared to 48% for those students not enrolled in the learning community.
- When asked how much the ENGR 1201 course added to their skills in *applying engineering principles*, 80% of those in the learning communities responded “a great deal” or “a lot” as compared to 32% for those students not enrolled in the learning community.
- When asked how much the ENGR 1201 course added to their skills in *critical thinking*, 66% of those in the learning communities responded either “a great deal” or “a lot” as compared to 30% not enrolled in the learning community.
- When asked to describe the *extent of their gains in understanding engineering principles*, 87% of those in the learning community responded “a great deal” or “a lot” as compared to 32% for those not in a learning community.
- When asked to describe the *extent of their gains in understanding the relationship between engineering concepts*, 84% of those in the learning community responded “a great deal” or “a lot” as compared to 27% of those not in the learning community.
- When asked to describe the *extent of their gains in using math to solve problems*, 92% of those in the learning community responded “a great deal” or “a lot” as compared to 37% of those not in the learning community.
- 96% of students in the learning communities indicated the linked courses had helped them to find students with whom they could study and felt those study groups would continue.

An additional unexpected result of the learning community was the impact on class attendance. The average number of absences in the learning communities ranged from 0 to 3 for a four day per week mathematics course. This number is much lower than what is traditionally seen in calculus or pre-calculus.

In the fall 2008 and 2009 surveys ninety-six percent of students in the learning community indicated a desire to take additional courses under the same model. Mathematics and engineering faculty worked with the WTAMU First-Year Experience Program to offer a learning community linking Calculus II and Engineering Statics in the spring of 2010. Mathematics and engineering faculty were motivated for this extended learning community model based on two factors: 1) the interdependence of applications of integration course objectives in Calculus II and Engineering Statics, 2) the pivotal position of these two courses in the engineering curriculum as freshman engineering majors often decide whether to continue in the engineering program based on their performance in these two challenging courses.

The overlap in course content and objectives between Calculus II and Engineering Statics occurs in the applications of integration portion of Calculus II which includes area, volume, surface area, moments, work and pressure against a surface by a fluid. This content provides numerous opportunities for PBL projects. The faculty however decided upon a fluid dynamics problem where students would experimentally and theoretically completely describe the resultant hydrostatic force exerted against a given submerged surface. Because the local pressure of a fluid is a function of the fluid density and depth at a given point, calculus allows the engineer to determine the total force on the submerged surface by proper integration of the local product of pressure and area. Calculus also provides tools so that engineer may determine the point of action of the total force and thereby determine if there is any moment or bending considerations that must be addressed. This is a prime example of the interdependence of engineering and mathematics and thus, a perfect problem for use in this linked-class PBL project. For the details of this project see [14].

The engineering and mathematics faculty worked to implement further connections throughout the course with topic specific assignments and additional material. A calculus class period was devoted to the theory of solving systems of equations and how to use technology to assist in this process. Engineering data which required a log scale for data analysis initiated the calculus content of logarithmic and exponential functions. Vectors and their operations are generally not discussed in the calculus curriculum until multi-dimensional calculus found in Calculus III. In order to assist the students in Engineering Statics, two calculus meetings were devoted to vectors, vector dot products and cross products. Anecdotal comments by the students indicated that the engineering principles were easier to understand having discussed the mathematics and geometry in calculus prior to the discussion of moments about a point and line in statics. The link between Calculus and Statics will be expanded to include moment and shear diagrams. Using point loads, and uniform and more complex distributed loads, the math students will apply the integration techniques to evaluate the shear and bending moments along a beam. The students will subsequently conduct experiments to determine the accuracy of these results. The students may also be asked to optimize placement of supports to minimize the bending moment in the beam under the various loadings.

Challenges Encountered with Implementation

In the fall 2007 pilot of the math/engineering learning communities, students were advised into one of the two communities at freshman orientation by a member of the WTAMU engineering or mathematics faculty. Very little explanation was provided over why they should choose to be in

this community. The feelings of the engineering and mathematics freshmen advisors was primarily that students have to take both of these courses, so why not take the linked sections? Surveys and focus groups were conducted at the conclusion of the semester to assess student attitudes about their experience. Students found it difficult to describe or assess the experience because they had no idea what to expect when they enrolled in the course. Subsequent learning communities have discussed on the first class day the retention and engagement literature on learning communities and their advantages as well as the program goals of building a supportive collaborative working environment to improve student success. Student feedback provided in focus groups and surveys have since been beneficial in helping to improve the program.

Although linked PBL experiences were incorporated into the Pre-calculus/Fundamentals of Engineering link since fall 2007, the mathematics and engineering faculty team experienced difficulty finding content that would link the curriculum prior to fall 2009. Although the student surveys indicated the results listed above, failure rates in the pre-calculus learning community remained consistently at the same level as the non-linked sections. In fall 2009, mathematics faculty implemented the method of initiating new algebra or trigonometry concepts with engineering application. The primary examples used were those developed in the Wright State *Introductory Mathematics for Engineering Applications*. [12] The mathematics instructor assigned additional engineering applications as homework problems to be incorporated into an engineering portfolio which was collected at the conclusion of the semester. The result was a dramatic increase in the percentage of students successfully completing the linked pre-calculus section, 83% earning a grade of D or above has compared to 50% for the remaining sections, also the historical rate for the learning community prior to fall 2009. Time will tell if this was the key factor, but it is encouraging.

Conclusion

A detailed analysis of retention is underway and necessary to determine the impact of the engineering learning communities on the overall goal of improved retention of engineering majors. Students are enrolled in the engineering learning community by self-selection. The unknown factor of inherent motivation cannot be controlled for. However, results to date indicate improved student performance in gateway mathematics courses from historical data and an improved intent to persist over students not enrolled in the learning community.

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