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Work in Progress: First-Year Curricular Change in Engineering at a Texas A&M University through Partnering with Physics

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Abstract

This work-in-progress paper will describe an effort at curriculum reform for the first year engineering program at Texas A&M University. A variety of motivations for, and challenges encountered in this effort are discussed, which highlight how educational change often takes place in tension between educational theory and institutional constraints. Preliminary discussion of results and future plans for assessment are discussed.

Introduction

Retention of engineering students continues to be a concern nationally [1]. There are perhaps additional pressures for improvement in retention at large state institutions, where legislatures keenly watch metrics such as retention, and where the institutions have a mission to serve people from across the state, regardless of socio-economic status or parental educational background [2],[3]. In this work-in-progress paper we present a case study of a recent effort in curricular reform to improve retention, and discuss some preliminary results.

At Texas A&M University first-year students in the College of Engineering begin as general engineering students for their first year, and then (ideally) start as majors in one of 15 engineering departments in their second year. Assessment of the retention rates once students were in a department using institutional data showed that departments were doing well at retaining students; typical retention rates to graduation for students who entered a department in sophomore year were 90% or greater (again from institutional data). The overall retention rate for the College from entry was much lower, however, typically around 70%; students were failing to make it out of their first year sequence into departments. This observation led to an investigation in 2016 into possible reasons for this drop-off in student retention before they entered a major. At that time, first year engineering students at Texas A&M typically[1] took a standard set of a math, science, and engineering classes: differential and integral calculus (MATH 151 and 152), introductory chemistry (CHEM 107) and engineering mechanics (PHYS 218), and a two-term sequence of Introduction to Engineering courses (ENGR 111 and 112). Analysis of student grades in these courses showed that the pass rates of the ENGR courses were typically above 90% (figure 1), while pass rates in the CHEM (not shown) course were generally between 80 and 85 %. Conversely, the pass rates of the MATH and PHYS courses (figures 2 and 3) were typically between 70 and 75%. The second physics course (electromagnetics and optics) also had an equally low pass rate. This indicated that improving pass rates in the math and physics courses might be a good first step in improving overall retention in the engineering college. However, since the math and physics courses were taught by departments in the College of Science, a joint effort between the colleges would be required.

[1] First year students ready to take the standard calculus sequence would take these courses. Students who were not calculus ready (evaluated based on a math placement exam) were delayed in taking this sequence.

Curriculum Committee and Curricular Constraints

Given the desire of the College of Engineering to make changes in curriculum to improve retention, and the openness of the College of Science to discussing changes in how the service courses it taught to engineering students were organized, a committee was appointed by the Deans of Engineering and Science to develop a plan for a new introductory curriculum for engineering students. There has been a long history of interest in integration between engineering and science curricula across the county [5], but with the efforts have come and gone. The bi-college committee (hereafter the Committee) consisted of roughly equal numbers of faculty from both colleges. Faculty from engineering tended to be from the larger departments (e.g. civil, mechanical, electrical, computer science), and were people who had previously shown interest in the freshman engineering program. Faculty from the College of Science came from the Departments of Math, Physics, and Chemistry, since these were the subjects in that college which first year students encountered.

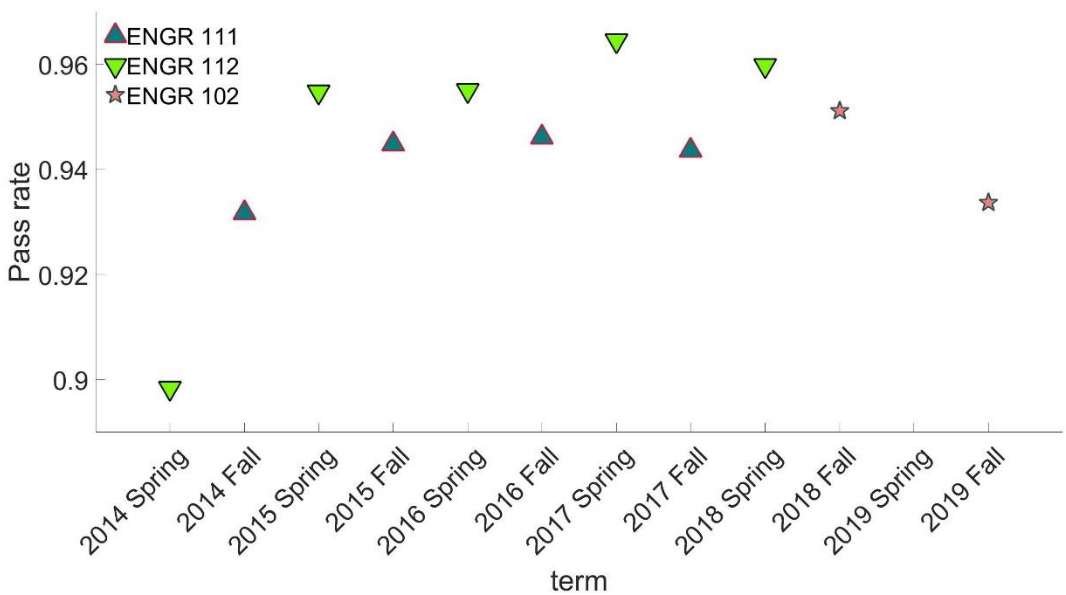

Figure 1 Pass rates for first year engineering courses

The Committee began its regular meetings in the fall of 2016. Planning discussions in the College of Engineering which had taken place before the creation of the Committee had envisioned scrapping the 6 first year science, math, and engineering courses (consisting of 20 credit hours), and replacing them with a set of new courses covering this material all taught under the College of Engineering (ENGR) aegis over the first two years of a student's education (one course per term for four terms.) When the Committee began to meet, however, this idea was assessed as unrealistic, for a number of reasons discussed below. The Committee had to consider therefore what changes were possible, what changes were optimal, and what would be the best means of effecting this change.

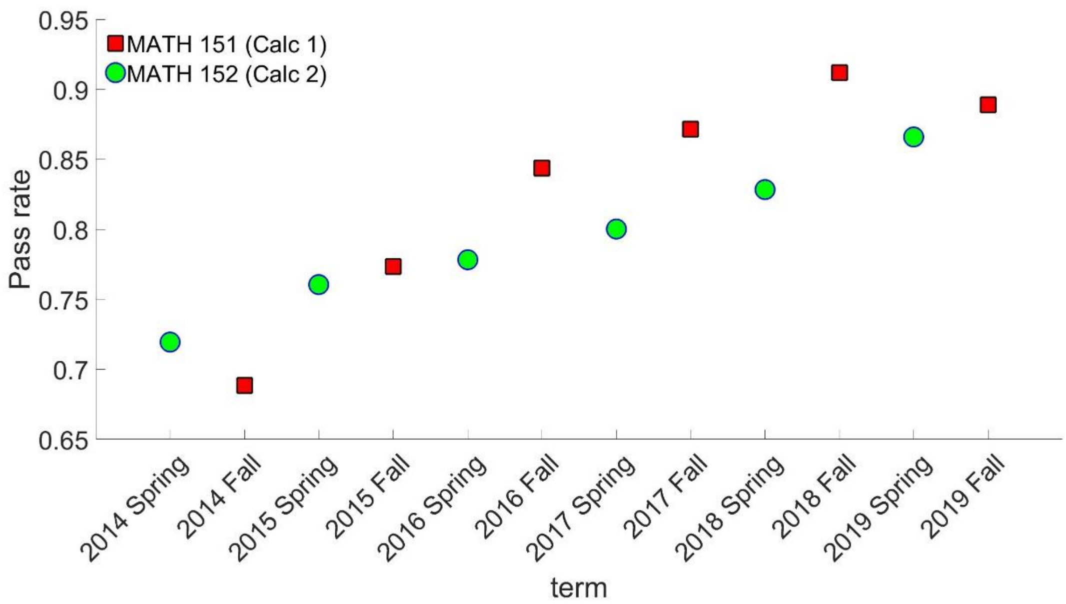

Figure 2 Pass rates for calculus courses taken by first year engineering students

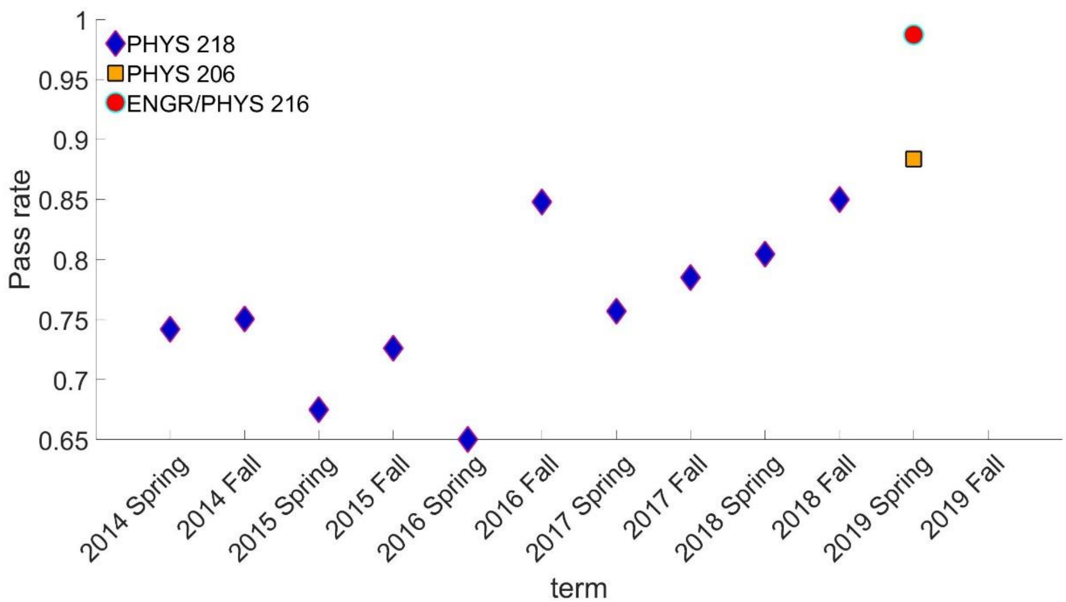

Figure 3 Pass rates for physics (engineering mechanics) taken by first year engineering students

Credit Hours Constraints

The plan for the series of new first year courses faced significant constraints. Some of these existed because no new credit hours could be added (or subtracted, but this was not an issue) to students' degree plans; the state requirement was 128 credit hours for graduation (with an engineering degree.) The zero-sum nature of the credit hour problem increased the political problems faced by any proposed changes; in order for credit hours to be added to any particular area, another area would have to lose credit hours.

Ultimately the problem with teaching all necessary math and science to freshman engineering students within the College of Engineering, or moving any credit hours from the science departments to the engineering college came down to allocation of funding. In the state of Texas, funding formulae decided at the state level allocate funds to universities based on the total number of student credit hours (SCHs) taken. (These are not the only funds the State spends on higher education institutions, but it does relate some portion of funding to the number of students taught.) Traditionally at Texas A&M this money from the State is then divided up among the colleges based on how many SCHs each college taught. The College of Science (with approximately 3000 students) received a significant amount of its state funding because of SCHs taught in service courses to students from the College of Engineering (with approximately 20,000 students.) Although the provost had stated to both the College of Science and the College of Engineering that no college would have a net loss of funds even if credit hour allocations changed, the potential of future funding losses due to reduced credit hours taught was a significant impediment for acceptance of any such changes by the College of Science.

The result of this constraint was the acceptance by the Committee that SCHs division in the freshmen engineering degree plans needed to be maintained at their current allocations, even though state funding went to the University, and the allocation within the University was an administration decision, not a statutory allocation. While the provost could state that funding between the colleges would not be changed even if the SCHs changed, there was concern that a future administration would not feel bound by a previous one's word, and reset the allocation of funds based solely on SCHs taught by a unit.[2] This sort of concern about the trustworthiness of institutional arrangements can exist regardless of the size of the institution.

Core Curriculum Constraints

Other constraints arose because of state core curriculum requirements. By state rule, core curriculum classes in this state must be open to all students, and must not have prerequisites. Engineering students satisfied the math core requirement with their first two terms of calculus (MATH 151 and 152.) They could not satisfy the math core requirement with more advanced math classes which most engineers took (such as Calc. III and differential equations) because these classes had prerequisites, and hence could not be part of the core. It became apparent to the Committee that any move to approval for new classes which would satisfy the math core requirement would take several years, and was not guaranteed approval. Hence MATH 151 and 152 were removed from the list of courses which would be revamped. It was agreed that future efforts would be made on improving math outcomes after the initial changes were implemented.

New Course Structure

The Committee solicited input from departments and engineering faculty on what was felt to be essential in a first year curriculum using a survey sent to department heads for dissimilation to

[2] Indeed, two years after the provost had made this promise, a new provost entered the office. There have been no changes in funding allocations, however.

their faculty and department curriculum committees. While there was agreement that the math and science topics currently being taught were appropriate, there was a great diversity in the responses on what engineering topics were desired. Given the string commitment by the college administration to the idea of a common curriculum for first year students some of the faculty input which was major-specific could not be used by the Committee. Based on the college-wide survey, the one item which faculty across the college agreed was necessary in the first year curriculum was computer programming. While the faculty and department administration of the Department of Computer Science were especially emphatic about this, the feeling that modern engineering students needed greater facility with computers and computer applications was shared across the college.

Given this input from the departments and engineering faculty, and with the goal of greater integration between the introductory physics courses and engineering, the Committee developed a plan for a new set of courses to be taken during a student's first three terms:

- ENGR 102 (1st term): this course would be an introduction to programming. The course would consist of one hour of lecture and three hours of a programming lab per week.
- PHYS 206 (2nd term): a lecture-only course on physical mechanics
- ENGR/PHYS 216 (2nd term): this course would be a lab-and-lecture course on physical mechanics, designed to be taken with PHYS 206. The format would again be one hour of lecture and three hours of lab per week.
- PHYS 207 (3rd term): a lecture-only course on electromagnetism
- ENGR/PHYS 217 (3rd term): this course would be a second lab-and-lecture course on electricity and magnetism, designed to be taken with PHYS 207 (a standard lecture course on electromagnetism). This course would also be in a one-hour lecture, three-hour lab per week format.

The 216 and 217 courses were co-listed with by ENGR and PHYS codes, in order to equate SCHs between science and engineering; there was no difference between sections with different course codes. Lectures in the joint ENGR/PHYS courses were not intended to replace lectures in the corresponding PHYS lecture courses, but rather to try to link the physics being taught with engineering applications and concepts. They also served to introduce some engineering topics (e.g. basic experimental statistics, basic project management) which many of the engineering departments indicated had value.

Implementation Committees

The actual development of course content was to be done by individual committees for each of the three courses. These implementation committees would have great freedom on what the students would actually do in the courses, so long as the overall three-course sequence developed by the Committee was followed. The committee for the programming course (ENGR 102) was led by two computer science professors, with additional members from the math department. The committee for the mechanics course (ENGR/PHYS 216) was comprised of faculty from the civil, mechanical, and aerospace engineering departments, as well as members from the physics department. Likewise, the committee for the electromagnetism course (ENGR/PHYS 217) consisted of faculty from the electrical engineering department and physics department. The different faculty appointed to these committees took different levels of ownership of the work. These differing levels of involvement meant that the vision of some faculty members was more strongly reflected in the committees' final work.

The implementation committees were formally independent of each other, save for the constraint that the later courses (216 & 217) were to use the programming language taught in the first course. Faculty on the implementation committees felt that Python was an appropriate choice for the new courses. There had been a number of changes in the programming language used in the freshman courses over the past two decades, so there was some concern about yet another change in supported language. Nevertheless, the Computer Science faculty in charge of content development for ENGR 102 were satisfied with the choice, so planning on the use of Python went forward.

The Use or Dis-Use of Educational Theory

An important question is to what extent the development of the new courses was guided by research on engineering education research and theories on engineering student success and persistence. The decision to use department faculty as the lead members of the Implementation Committees had the perhaps-unintended result that focus in the course development process was on what the engineering departments felt the students should know (content), rather than on a course structure which was aligned with educational research on what methods work to improve persistence (method.) Somewhat ironically, it was the Physics Department faculty who were most guided by research findings from the STEM educational literature in their development of the lab activities in ENGR/PHYS 216 and 217. These labs were designed as open-ended explorations of the mechanics and electromagnetics topics, using new equipment developed by the Physics department faculty.

There was significant discussion both in and outside of the Committee that this new structure would lead to a move away from the type of project-based learning in the engineering program which had been in place at Texas A&M for the previous two decades [4]. Ultimately, the desire to work with the College of Science on improving outcomes in physics courses and the constraints on the credit hours led the Committee to its recommendation. In a sense, time devoted to project-based learning was sacrificed to allow greater integration between the physics and engineering units.

Starting in the summer of 2017, the implementation committees started their work on the new course materials. While it had been intended that these committees would work simultaneously, the time pressure was greatest on the committee developing material for ENGR 102, which would be taught for the first time in the fall of 2018. Since ENGR/PHYS 216 was not scheduled to be taught for the first time until spring of 2019, and ENGR/PHYS 217 until fall of 2019, the implementation work of those committees lagged behind.

The topics are presented for each course in tables 1 through 3. During the development of the ENGR/PHYS lab-lecture courses it became apparent that some lecture time would need to be devoted to explaining certain aspects of how to do the labs. The Physics department took the opportunity of the course revamping to develop new lab equipment, and students would need instruction in (among other things) analog-to-digital sampling, data processing, and the Linux operating system in order to use the equipment. Since much of this material would be of use in later laboratory courses, its inclusion in the lecture portion of the course was thought to be beneficial.

Table 1 ENGR 102 topics by week

Week	Class Topics
1	Introduction to Course, Engineering, and Programming
2	Sequential Steps, Variables, Assignment, Data Types
3	Input/Output and Modules and Calling Functions
4	Conditionals and Boolean Expressions
5	Loops and Iteration
6	Creating and Testing Programs and Basic Debugging
7	Arrays and Lists of Data
8	Top-Down Design of Programs
9	File Input and Output
10	Using Engineering Modules in Python
11	Writing Functions, Scope
12	Functions and use in top-down/bottom-up design
13	Systematic Debugging
14	Topic TBD by instructor/section

Table 2 ENGR/PHYS 216 topics by week

Week	Lecture	Lab
1	Introduction, Propagation of Error	
2	Finite differences	Introduction to the Air Table
3	Intro to Excel	Visual Odometry
4	Basic Experimental Statistics	
5	Confidence Intervals	Motion Control
6	Universal Account Equation	
7	Particle Statics	Force Evaluation
8	Conservation of Momentum (Collisions)	
9	Rigid Body Statics	Collisions
10	Center of Mass and Angular Momentum	
11	Harmonic Motion	Rotational Motion
12	Engineering Ethics (1)	
13	Engineering Ethics (2)	Harmonic Motion
14	Art & Engineering (1)	

Table 3 ENGR/PHYS 217 topics by week

Week	Lecture	Lab
1	Lecture 1: Meet Your DAQ	
2	Lecture 2: Intro to Arduino	Intro to DAQ
3	Lecture 3: More on Arduino	Intro to Arduino
4	Lecture 4: “Resistance is Futile”	Arduino Display
5	Lecture 5: Data Analysis & Project Management	Electric Field and Electric Potential
6	Lecture 6: CPM & some more on Resistances	
7	Lecture 7: Magnetic Fields	Resistances and Resistivity
8	Lecture 8: Lorenz Force	
9	Lecture 9: Topics on Electric Power	Magnetic Fields
10	Lecture 10: LRC (time varying) circuits	Lorenz Force
11	Engineering Ethics (3)	Induction
12	Engineering Ethics (4)	
13	Engineering Ethics (5)	Time-varying circuits
14	Art & Engineering (2)	

Initial and Future Assessment of Results

The first cohort to complete all three courses finished in the fall of 2019. The amount of data available for assessment is therefore quite limited. Student success rates based on grades within the courses continued to be high as compared with the previous course sequence. With respect to assessment more grounded in educational theory, because of the focus on content rather than method in the course development process, the assessment of the efficacy of these curricular changes needs to be developed after the changes were made, rather than being part of the design from the beginning.

It is intended that future research into the impact of the curricular changes will follow two tracks. First, quantitative and qualitative feedback from the College Departments on the preparation level of the students accepted into their majors will be collected, to determine the extent to which the first year program is meeting its ultimate goal of preparation of students for further engineering study. Second, the program will make use of the demographic data available in the university databases, and a results from a questionnaire on organizational engagement and goal commitment distributed to a subset of the 4000 students in each cohort to examine causal relationships between these factors and students persistence and success. Work in both of these tracks will be ongoing as the number of students passing through the program continues to grow.