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A matrix map method for coordinated undergraduate curriculum improvement in Electrical Engineering and other programs

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A matrix map method for coordinated undergraduate curriculum improvement in Electrical Engineering and other programs

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Abstract

Traditionally curriculum improvements are often based on comparisons with similar programs at other universities. In this paper we describe an alternative, generalizable method for coordinating curricula that does not require such comparisons and furthermore allows one to tailor the program to fit the specific needs of the students. This method involves the creation of program-wide "fundamental topic maps". This mapping approach to curriculum development sits between the traditional models for curricula (courses devoted to specific, isolated topics) and those that are integrated in nature. These maps can be used to implement continuous improvement of the curriculum.

1 Introduction

Many engineering fields cover broad areas of study that require many years to master.[**1**] What is covered in a specific engineering field at a given school will depend on historical and internal dynamics within that college/university.

A prime example of a broad engineering field is Electrical Engineering (EE). EE is a relatively young but very broad field of study.**[2]** Currently, the *CollegeBoard* lists EE as "Electrical and communications engineering" or "Electrical and computer engineering" (ECE).**[3]** In general, electrical engineers deal with any engineering topic involving electric/magnetic fields and their applications. The field encompasses a wide range of subjects, from electric generators for power generation to communication systems.**[4]** Indeed, the *CollegeBoard* **[3]** lists 8 major concentrations within ECE. These include: Electromagnetics, Electrical power, Electronic design, Communications systems, Computer systems, Digital systems, Control systems and Telecommunications. For the purposes of this article, and consistent with the internal needs of the UT Dallas EE program, we will simplify this list to the following four areas:

Applied Science (Electromagnetics/Optics/Devices)
Power (Electrical power conversion)
Circuits (Analog and digital circuits)
Systems (Communications/Digital/computer/etc)

It should be noted that each of these areas could be the focus of an entire department at some universities.

Because of the large number of topics within the general field of EE, until a number of years ago a typical Bachelor of Science (BS) in EE would take an average student more than 5 years to complete. **[4,5]** In fact, the *CollegeBoard* lists 16 major junior/senior level classes within ECE, spanning a wide range of topics. Many of these classes developed out of the historical growth of the general field. In addition, when one university would develop a new sub-topic, other competing universities would often follow suit. This consistency among universities was further increased by the requirements of accreditation boards such as ABET.[**6**] Under the old

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accreditation standards, the department had to have a number of major elements, including a specific core curriculum related to the explicit engineering program. In comparison, the more recent ABET "Engineering Criteria 2000" allows the universities more flexibility in the exact curriculum but requires a better understanding of the student learning outcomes. The end result of all of these external and internal pressures was that students would often have to complete ~150 hours of course work, including general study courses, necessary mathematics and basic science courses, to obtain a BSEE degree. **[7,8,9]**

To reduce costs associated with the BSEE and other engineering degrees, oversight boards and regional legislatures have forced most universities to require no more than ~120 credit hours to graduate, making them ~4-year degrees. It should be noted there are still a few major universities that require ~150 hours to graduate – but the number of those universities is small. **[7,8,9]** The reduction in allowed credit hours has been dealt with in a number of ways. Some schools reduce the credit hours awarded for a course while maintaining a larger number of contact hours. Others push more information into the same amount of time. Still others cut some aspect of the broad ECE program. Almost all schools use some combination of these techniques to arrive at a ~120 credit BSEE. Unfortunately, what is cut and how it is cut plays a major role in the quality of the education – and the cuts are carried out in uncoordinated ways, often with unintended consequences.

Despite the reduction in the allowed credit hours, employers still expect many things from fresh BS graduates. These desires range from a deep knowledge of specific topics to hands-on skills needed to operate the latest tool in the industry. In effect, the desires of many companies have been described as: "Wanting a new BSEE to be 23 years old with five years of experience".**[10]** Most universities do not have the infrastructure required for such an education, much less the knowledge of how to carry it out.

The UT Dallas EE department, like most programs in the US, found itself stuck between the competing constraints imposed by governing agencies and private industry. Below, we describe our approach to creating a high quality educational environment. The first part of our approach to improvement used standard techniques: examination of program outcomes and comparing our curriculum to those of comparable departments. From this we built a new technique for optimizing (controlling and improving) our curriculum: "*curriculum topic mapping*". In this article, we show how our new topic mapping model is linked to an understanding of how people learn and how creative individuals develop new ideas. Further we show that this topic-mapping model can be used both to develop a new curriculum and to improve an existing one, giving greater control over the learning environment to both the faculty and the students and thus improving the general learning environment. We also argue that the topic-mapping model can be a useful part of most universities' accreditation processes.

2 Technical Approach

It is typical for most engineering departments in the USA to use the ABET accreditation 'a' through 'k' criteria **[6]** to look for ways to improve an educational program. Most departments will collect data through a variety of methods, including: (1) class evaluations by students, (2) class evaluations by faculty, (3) exit surveys for seniors, and (4) employer Industrial Practice Programs (IPP) exit surveys. According to the ABET guidelines in place at the time of this work, surveys of individual students were not valid review methods, leaving only class evaluations by faculty and IPP exit surveys as valid data. Unfortunately the data from IPP exit surveys are often not statistically significant, leaving only faculty evaluation of classes as a tool for assessing student performance. Typical of this approach are the data shown in **Figure 1**. There, we show the average faculty evaluation of ABET criteria for a single semester in UT Dallas's Electrical Engineering program, with 5 being excellent and 1 being poor. The averages are shown based on class level, from freshman (1XXX) to senior (4XXX), as well as an average for all undergraduate courses. Such global evaluations are typical in program reviews. Unfortunately, as can be seen in the figure, there is very little useful information in such global reviews since the results are tightly clustered and show little discrimination across courses. Although one may wish to use such data for curriculum improvement, it is obvious that only very large-scale problems would or could produce statistically significant variations in the assessment measurements.

While the average values from our ABET assessment suggest our students were generally doing well, we desired to improve significantly the quality of our students' education. For example, based on graded work, our students often do very well on one topic within a given course but not as well on other topics. In general, the department ascertained through a series of discussions among the faculty members that there were five main issues associated with difficulties in improving the quality of our students' learning.

1) There was a disagreement among professors about what was to be taught in a specific course.
2) There was a lack of connection between classes, typified by
    a. A lack of physical understanding of what the math means.
    b. Students' inability to "see the big picture".
3) There were disconnects between classes and long-term industrial requirements.
4) There was a wide variation among students' performances. Examples include,
    a. Older students tended to take longer to complete the program.
    b. Older students tended to be better motivated.
    c. Older students tended to have weaker math skills.
    d. Part-time students took a long time between subsequent classes.
    e. Part-time students tended to mix class levels, taking upper-level and lower-level classes simultaneously.
5) There were a limited number of credit hours for the BSEE program.

We know that these issues are present at almost all universities. While these issues had been recognized for many years at UTD, we did not have an effective means of tackling them globally. As we shall discuss below, our topic-mapping model provides us with a feedback mechanism to address these issue effectively, in a coordinate fashion across the curriculum. First, since we understood that some of the educational quality issues had to do with the different backgrounds of the students, we wanted to determine how other universities dealt with similar students. Thus, our first approach to improve the curriculum within our department was to examine what comparable departments were doing. Here, we determined the "core" required classes in 10 comparable universities across the US, as well as the "core" classes as described by the *CollegeBoard*. It was within this study that we determined that it was effective to divide the EE program into "Freshmen/sophomore level math", "Freshmen/sophomore level science", "Applied Science", "Circuits", "Systems" and "Power". The first two of these broad topics are often taught outside of the department, as is the case at UT Dallas. The latter four are often taught inside an EE department. UT Dallas has concentrations in "Applied Science", "Circuits" and "Systems". Unfortunately, our comparison with other universities did not reveal substantially useful information. We found that some schools had more required courses and some had fewer. Some universities had more contact hours per credit hours, others had fewer. In general, there was no obvious method for improving the quality of the education by examining just the required courses at other institutions.

The second part of our approach was to examine how the average student learns. Kolb and Fry **[11,12]** described learning as a cyclic process starting with "experience" followed by "process", "generalize" and then "apply". Based on this approach, we asked, "What information are our students learning in each of our classes?" and "Where do they apply that information?" This is not just an issue of specifying pre-requisites, but in fact is a curricular review implementation of the Kolb-Fry model:

Experience => Process => Generalize => Apply => Repeat.

From this process we developed a global map of the EE curriculum based on the description of each course as given in the university's course catalog. After four iterations of this map with faculty participation, we developed a map of all of the "skills" learned in each class and where those skills might later be employed. Part of that initial map is shown in **Figure 2**.

Unfortunately, this second method of examining our curriculum, while better, also failed to reveal useful information. This failure was due to three reasons: 1) Learning specific skills, such as programming in a given language, while useful does not easily map from course to course. 2) By examining just the "skills" learned, we failed at determining what the students were learning in a broader sense. 3) Such a "skills-based" curriculum- is analogous to teaching a student how to fix circuit boards – by examining them one at a time. If instead, one teaches the students how to fix the boards in a more general fashion, they can potentially fix all circuit boards. We note that a number of schools do a very good job teaching students using skills-based curricula. However the focus of those schools tends to be oriented more towards educating technicians. This is not what we are trying to do at UT Dallas.

Our third approach was to examine the curriculum using the basic ideas of "Metacognition" and "concept maps". Metacognition has been described as a process in which one uses awareness (or knowledge) of the learning process in order to improve the learning process. **[13,14]** The use of concept maps is a tool often used in the metacognition method. Using concept maps, one links different ideas together in order to build a conceptual model of a topic. Indeed, in 1981 it was proposed by J.D. Novak that Biological Sciences could be better taught using concept maps and this has been extended to other fields including engineering. **[**Error! Bookmark not defined.**,15,16,17]** This idea has been examined by numerous authors and quantitative and qualitative methods of analyzing concept maps have been developed. **[18,19]** It has been repeatedly shown that introducing students to concept maps can help them develop metacognitive skills. **[20,21,22,23,24]**

Concept maps come in a variety of formats. **[**Error! Bookmark not defined.**,13,25,26]** The simplest concept map formats include "Spoke", "Chain" and "Net". Spoke shows no relationship among concepts, although those relationships are critically important in most technical fields. Chain implies a simple sequential building process. The chain map misses the important notion that one frequently puts multiple, disjointed ideas together to develop new ideas and technologies. The net map implies that one can learn pieces of the subject in a random order. Again this is clearly not true for most technical fields.

We want to apply the notion of concept map to the examination and evaluation of our EE curriculum. However, none of these basic map configurations provided a good structure for doing so. We argue that an 'interwoven' combination of chain and net seems to be appropriate for examining curricula, at least in technical fields. **[13]** This interwoven combination is consistent with the observation that the best students develop an internal concept map that allows them to use content from several courses, leading to critical thinking about new problems and issues. **[13,14]** Our 'interwoven' mapping model mimics this process and helps to teach all students to develop such internal concept maps. (While the procedures are similar, we point out that we are mapping topics rather than concepts.)

Traditional engineering curricula are hierarchical in nature, even if the content is carried through many levels. Likewise, integrated (or problem-based) curricula (in which topics are introduced "just in time" as needed) are spoke-like in nature and thus tend to miss important links between dissimilar topics. Hence, our topic-mapping model seems to fit between the traditional and problem-based models. We will examine these structural differences and similarities in future articles. We emphasize that the interwoven topic map can be used as both a curriculum analysis and a design tool. Thus, we gain many of the advantages of each of the two standard curriculum approaches, with an added benefit of a broader understanding of the structure of the curriculum.

To build the interwoven topic map of our curriculum, we first ordered the classes in a manner used a chain-like concept map. Our specific ordering was based on the hierarchy (sequence) with which the students are typically take the topics. Thus we placed at the beginning of the chain the basic math and science courses that all engineering students must take in their first years in college. This was followed by the mathematics courses offered by the EE department, which the students often take before any other engineering courses. We then added the core required courses that all BS EE students must take at UT Dallas and then finally the EE elective courses.

The second step in building the interwoven topic map asked all of the EE faculty members to determine the fundamental topics that they taught in their undergraduate classes. Here we had to impose limits. This was done for three reasons. 1) Some faculty initially provided very long lists. 2) We felt that a truly fundamental topic could not be taught in a single class period. 3) Successful courses really should have more than one fundamental idea. Thus, initially we somewhat artificially limited the number of fundamental topics to a maximum of 6 and a minimum of 3. For classes with more than one instructor, as is typical for our department, we asked that all of the instructors arrive at a single set of fundamental topics. (For our department we have specific “course owners” for each course. These owners are typically senior faculty members who teach or have taught the course. Their job is to work with all of the instructors to ensure consistency from section to section.) At the end of this step we had approximately 200 fundamental topics listed. This number includes those taught in required Math, Physics, Chemistry and Computer Science courses.

The third step in building our interwoven topic map asked all faculty members to determine the fundamental topics taught in other classes that they consistently used in their undergraduate classes. In addition, we asked them to indicate any possible honors topics for their classes and any concerns that they had about a given course.

Finally we added to this, all of the pre-requisites, co-requisite and pre-pre-requisites. **[27]**

In total this process took seven iterations over a 12-month period (~ summer 2006 to ~ summer 2007) to determine the basic map for our complete curriculum. While most of the input for the map came directly from the faculty, some input came from our Industrial Advisory Board and our students. This outside information was gathered as part of the fifth iteration. A small portion of our completed topic chart is shown in **Figure 3**.

The map was created and is read in the following manner. All of the program core classes are listed on both the left vertical axis and the top horizontal axis. The second row from the top lists all of the topics taught in all of the courses, with the course topics aligned with the course names on the top row. To look at the specifics of a given course, one finds that course along the left vertical axis. As one moves along that row toward the right, one finds boxes are filled with ‘U’ for topics used in the course, ‘T’ for topics taught in the course, ‘H’ for possible honors topics for the course and ‘C’ for topics that might cause concern in the course. Once the boxes are filled, one can use the ‘U’s to accurately determine courses that should be co- or pre-requisites. The topics of those courses are marked in green and pink respectively. Additionally we have marked courses that are pre-requisites of pre-requisites with light pink. We have also marked the main topics in orange, honors topics in dark green, and topics of concern in red. Such a color-coding allows all members of the department to ascertain quickly the detailed structure of the complete curriculum – including what a student would be expected to know prior to taking a given course. Further, such a mapping allows the faculty to identify problems in the curriculum structure.

3 Results

We have begun to use our interwoven topics map to improve the quality of the undergraduate education and student learning in EE at UT Dallas by employing a systems approach. To do this, we created five *ad hoc* committees to examine different aspects (or subsystems) of the curriculum. Each group was made up of the instructors/owners of the courses falling within our internal subcategories for electrical engineering: applied science, circuits and systems. In addition, we had groups focused on labs and math courses. The purview of each committee spanned multiple classes, with often more than one committee examining the same class. For example, our Electronic Devices course (EE3310) was covered by both the Applied Science committee and the Circuits committee because it has some elements of both of these broad topics. In addition, it was also examined by the Lab committee, since it also has an associated laboratory. Each group considered a number of issues including:

1. The current interwoven topics chart
2. The end of course student comments/reviews from the last two semesters
3. Course syllabi
4. Course catalog descriptions

In addition, the Lab group considered previous discussions within the undergraduate committee and a report on Laboratory classes at other Texas universities. While going through the review the following questions were asked:

1. Are the prerequisites for the course appropriate?
2. Is there significant overlap with other courses?
3. Do the end-of–the-semester comment forms raise any concerns and can they be addressed by altering the interwoven curriculum map?
4. Do catalog descriptions match the topic map?
5. Do the syllabi match the topic map?

Our first complete pass through the entire curriculum map was done over the summer of 2007 – resulting in major changes to our courses in the fall of 2007. (A second complete pass through the map was also completed over the summer of 2008.) In the summer of 2007 we made the following changes to our curriculum.

1) Eight topics were merged
2) Five topics were divided
3) Many topics were reworded
4) Nine pre-requisite changes were made
5) Two classes with heavy overlap were discovered and the overlap corrected.

We will go though these changes in order, citing some examples:

(1) Merged topics were often within single courses – with the initial topics being too narrowly focused or misdirected. However, in some cases the topics occurred in several courses. In such cases, we have removed the overlap between courses by leaving the topic in only one course. This change will allow the instructors to spend more time on the other topics – providing a firmer foundation for the students. In addition, it will allow the students to understand which topics are the most important.

    Example: Within EE3300 (Electronic Devices) the four topics "3D cubic crystal model", "Metal-semiconductor junction characteristics/Experiment", "Haynes-Shockley experiment" and "Semiconductor material properties" were merged into a single topic "Semiconductor material properties". With this change, the instructors of the course now understand that they should not overly focus on the

Haynes-Shockley experiment, as doing so removes the focus from what the students need to understand.

(2) Divided topics were carried across sequential courses. In these cases, a topic would be started in one course and carried into a later course and treated in more detail. Thus we rewrote the topics to reflect the move from introductory to advanced examinations of the same topic.

Example: Across EE3302 (Signals and Systems) and EE4361 (Digital Signals Processing) the topic of z-transforms was divided into “Intro to Z-Transforms” and “Z-Transform and its applications”. With this change, the instructors of the course now understand the level at which they should examine a subject.

(3) Rewording of topics was undertaken primarily to make the link between courses stronger. Often a topic might be described one way within a course but that description was not appropriate in other courses that made use of the same topic. By rewording the topics we were able to firmly establish those links or to show the differences.

Example: Both EE4360 (Digital Communications) and EE4365 (Introduction to Wireless Communications) had some of the same fundamental topics. However there were differences in how they were applied. That distinction has to do with the fact that wireless communication has to deal with ‘fading channels’. Thus the topics in EE4365 were changed to reflect the ‘fading channels’ – while still exhibiting the similarities.

(4) Pre-requisites have now been changed to reflect what is truly needed in each class, by examining which topics were used in each class and where they were taught. These changes have reduced our minimum graduation time from seven semesters to six, by reducing the maximum pre-requisite chain from seven to six.

(5) In the past, we would make changes to individual classes to correct known problems. Unfortunately such changes would sometimes lead to a “de-linking” a course and its pre-requisites. We are now able to easily identify those de-linkings. Such linkage (or lack thereof) is readily observable in the full map of the program.

(6) Finally we identified two classes with heavy overlap. Both are senior-level elective courses – and thus taken by only a portion of our students, with few taking both. Nonetheless, the specifics of those courses were examined by the course owners and instructors to minimize the overlap. This process resulted in a broader range of courses for our students, without any increase in credit hours.

Example: EE4367 (Telecommunications Switching and Transmission) and EE4390 (Introduction to Telecommunication Networks) had many of the same fundamental topics. This situation was rectified by altering the focus of the courses to: EE/TE 4367 (Telecommunications Networks) and EE4390 (Computer Networks). As with item 3, an effort was made to reflect the differences while still exhibiting the similarities.

In addition to these structural improvements, we also see evidence that our students’ understanding is improving, **Figure 4**. We find that the students’ fall semester grade-point average (GPA) of all students in all undergraduate electrical engineering classes increased from 2.62 to 2.79 – counting those students who withdraw from the class as a failure. . If we exclude from the data the students who withdrew, we find the semester average GPA increases from 2.75 to 2.88. This corresponds to GPA increases of 0.17 or 0.13. Since the typical GPA standard deviation (σ) is 0.07, the observed increases are approximately 2 σ. In addition to this increase in GPA, we also observe a significant decrease in the percentage of students dropping courses, from 4.5% to 3.2%. Finally, we preformed a linear least-squares fit (ANOVA) of the GPA data from Fall 2005 to Fall 2008. Our independent variables were: (a) year in which the course was taken,

(b) number of credits for the course (e.g. 1 credit labs vs. 3 credit lecture courses), and (c) the particular course taken (e.g. advance engineering math vs. electromagnetism). The single dependent variable was the average GPA for a given course in a given year. The results are found in the following table:

Parameter	Prob >F
Credits	< 0.0001
Course	< 0.0001
Year	0.0437

Table I. Comparison of the one-way ANOVA F-test of the independent variables in a least-squares fit of overall EE GPAs in fall semesters between 2005 and 2008. Only the year in which the course was taken shows statistical significance.

The results of the fit indicate that the year in which the course was taken was the dominant independent variable, confirming that students who took the courses after the changes identified by the topic mapping method were implemented did better than students who took the courses prior to the changes.

We note that for a multitude of financial, legal and ethical reasons it is simply not possible to maintain a control group for comparison while making such changes. As such, we recognize that while the effort we have described in this article was the main effort to improve our undergraduate curriculum, other factors might affect the GPA data. For example, the university-wide average SAT score for entering freshman increased slightly from 1239 in 2003 to 1248 in 2007. On the other hand, over the same time period the university-wide class ranks of our incoming students have been effectively constant with 96±1% in the top half of their high school classes, 73±1% in the top quarter and 42±1% in the top ten percent. These data suggest that there were not significant changes in the student population over the time period of interest. Changes in feeder classes (calculus and physics) might also play a role in the observed GPA increase. However, substantive changes were not implemented in those courses until the spring of 2009, as part of a summer and fall 2008 university-wide alignment process based on this topic mapping tool. Further, grades in those feeder classes had not changed significantly over the period of interest. Finally, individual instructors might have changed teaching practices. However the department typically offers multiple sections of many classes, often with different instructors.

4 Future Possibilities

There are numerous ways in which such interwoven topic maps can be used to strengthen education. We will examine a few of them that we are planning at UT Dallas.

The first, and most obvious use for the fundamental topic map is to manage and improve the curriculum within a given department. There are two methods to achieve this control – both of which have been or are in the process of being implemented within our department.

1). After the end of each semester, the instructors and course owners get together and examine the comments from the students' end-of-semester course evaluations. They also discuss course-specific feedback from our Industrial Advisory Board. The faculty then write short reports describing strengths, weaknesses, and possible improvements of all courses taught that semester. (These reports often cover multiple sections and multiple instructors.) During each summer, these reports, along with syllabi, course catalog descriptions and our fundamentals chart are examined by ad hoc committees headed by senior faculty and made up of appropriate course owners and instructors. Reports from these ad hoc committees are then compiled by our curriculum committee, which makes recommendations for changes to the general faculty. By using this method, we can correct issues while at the same time examining how changes might affect the curriculum as a whole. Also, instructors can use the chart to plan examples that can be applied in later courses – thereby providing tighter links between topics taught in one class and used elsewhere.

2) A second way to manage and improve the curriculum is through applying control over the details within each course. In a traditional setting, each instructor would set the structure and order of the topics, as well as the detailed subtopics covered within each section of the course. Making use of the map, the course owners and instructors can further lay out the structure of the course. Thus for each fundamental topic, we will have an agreed upon set of subtopics and the order in which those subtopics should be taught, allowing us to maintain consistency from section to section. In addition, one can use these subtopics to gather standardized assessment criteria needed for accreditation. We are currently gathering such information to generate "standardized" syllabi for each course within the department. It should be noted that as groups, the course instructors still "own" the details of the topics taught within a course.

Thus far, we have described alignment of courses only within a department. Clearly this concept can be extended to alignment across departments and across schools with the University. The topic mapping can also be extended externally, particularly to community colleges, high schools, and the needs of local industry, thereby providing a global picture of the engineering educational system.

In the Fall of 2008, UT Dallas developed topic maps across multiple departments and multiple schools within the university. Those maps have resulted in a number of major changes to core math and physics courses. These efforts are continuing by developing detailed alignment and articulation agreements with local community colleges.

The interwoven curriculum topic map described here bridges the gap between a traditional curriculum model, with its isolated courses, and a problem-based (integrated) curriculum model[**28]. We have demonstrated that it is a versatile tool for curriculum development and curriculum review and enhancement at multiple levels.** In addition to being useful for faculty members, these topic maps can be used to help students understand what they are learning. Often we find students "missing the forest for the trees". Being able to understand the big picture will allow students to know how multiple topics are linked – and why they need to study various topics. To help facilitate this process, we have posted a printed copy of the chart in the hallway of the engineering building, where students can examine it. We also plan to create a website where they will be encouraged to 'browse' the chart.

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Figures

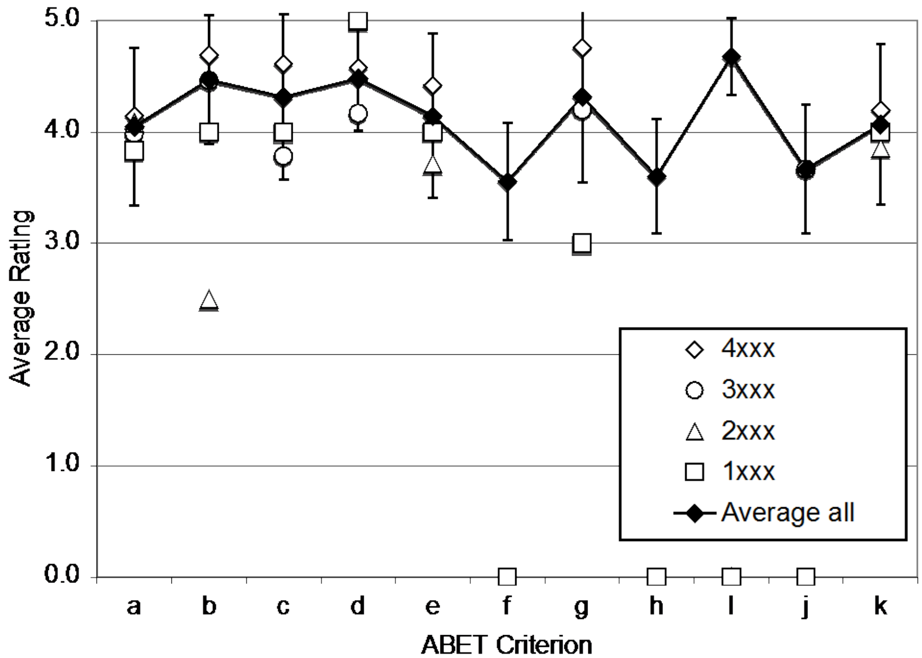
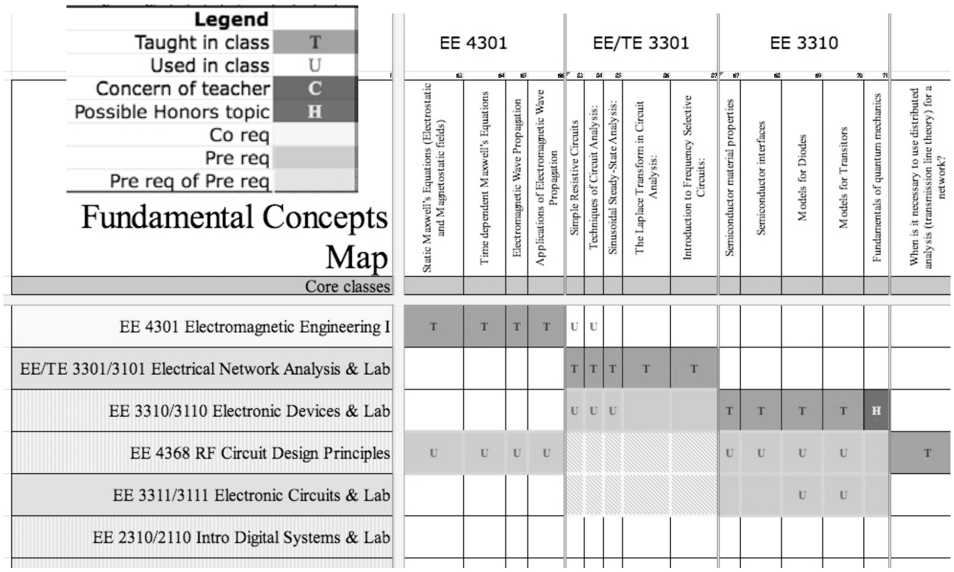


Figure 1: Average evaluation of ABET criteria for a single semester in UTD's Electrical Engineering program. Such global evaluations are typical in program reviews. Unfortunately, there is very little useful information in such reviews.

Skills: T(Taught)/U(Used)	EE 3300 Advanced Engineering Mathematics	EE/TE 3301 Electrical Network Analysis	EE 3302 - Signals and Systems	EE 3310 Electronic Devices	EE 3311 Electronic Circuits	EE 3320 Digital Circuits	EE 3341 – Probability and Statistics	EE 3350 Communications Systems
Linear Algebra	U	U			U			
Matrices	U	U						
Vectors	T							
Determinants	U	U						
Eigenvalue and Eigenvectors	U		U					
Vector differential calculus-Gradient, Divergence, and Curl	T							
Inner product, Cross Product	T							
Curves, Tangents, and Arc Length	T							
Velocity and Acceleration	T							
Vector Integral calculus-Line and Surface Integrals	T							
Integral Theorems-Green's, Divergence, and Stokes	T							
Complex Numbers	T	U	U	U				U
Complex Integration	T							
Complex Analytic Functions	T							
Power Series, Taylor Series, Laurent Series	T							U
Residue Integration Method	T							
Circuit Elements		T						
Simple Resistive Circuits		T						
Techniques of Circuit Analysis: Node-Voltage Method, Mesh-Current Method, Source Transformations, Thevenin and Norton Equivalents, Maximum Power Transfer, Super Position		T						
Operational Amplifiers		T						

Figure 2: Initial "skills" chart showing which skills were taught ('T') in which class and where those skills were used ('U') in a later class.



Core classes	Static Maxwell's Equations (Electrostatic and Magnetostatic fields)	Time dependent Maxwell's Equations	Electromagnetic Wave Propagation	Applications of Electromagnetic Wave Propagation	Simple Resistive Circuits	Techniques of Circuit Analysis:	Sinusoidal Steady-State Analysis:	The Laplace Transform in Circuit Analysis:	Introduction to Frequency Selective Circuits:	Semiconductor material properties	Semiconductor interfaces	Models for Diodes	Models for Transitors	Fundamentals of quantum mechanics	When is it necessary to use distributed analysis (transmission line theory) for a network?
EE 4301 Electromagnetic Engineering I	T	T	T	T	U	U									
EE/TE 3301/3101 Electrical Network Analysis & Lab					T	T	T	T	T						
EE 3310/3110 Electronic Devices & Lab					U	U	U			T	T	T	T	H	
EE 4368 RF Circuit Design Principles	U	U	U	U						U	U	U	U		T
EE 3311/3111 Electronic Circuits & Lab												U	U		
EE 2310/2110 Intro Digital Systems & Lab															

Figure 3: A small portion of the current fundamental topics map. This map shows where fundamental topics are taught ('T') and used ('U'). In addition, we have mapped our co-requisites, prerequisites, pre-prerequisites. Also mapped are possible honors topics and areas of concern.

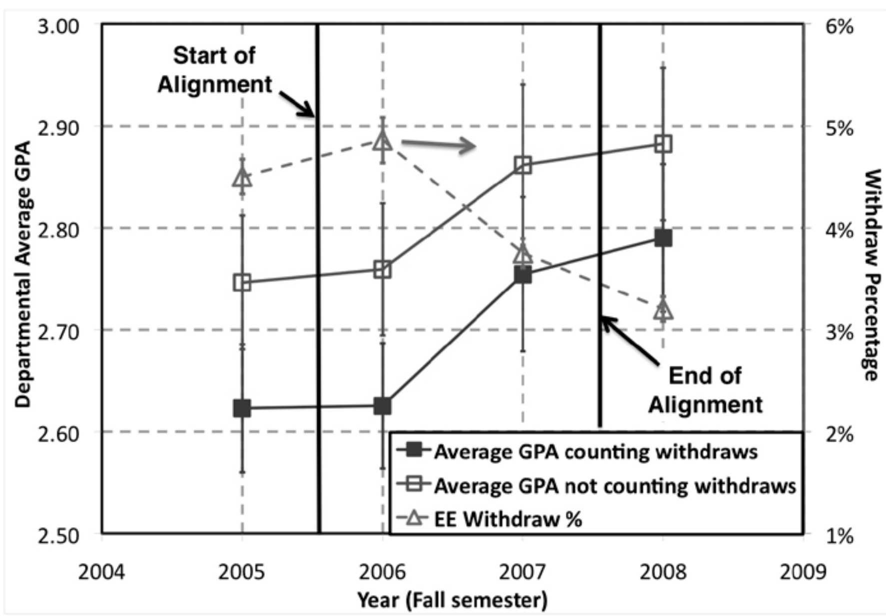


Figure 4: Average Departmental GPA for Fall semesters during the systematic change to the curriculum. Closed boxes show the average GPA when students who withdraw are counted as having received an F. Open boxes show the average GPA when the students who withdrew are not counted. Finally open triangles show the average withdraw rate for all classes within the department. All three show significant improvements that correspond to period in which the major alignment of courses occurred.

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