Redesigning Design Education at Trinity University

Diana Glawe, J. Paul Giolma

Department of Engineering Science
Trinity University

Abstract

Trinity University has long embraced an engineering design approach that spans the entire undergraduate experience. In the 1980's the foundations for the current eight-semester sequence were laid; in the 1990's, bridges were made between design courses, engineering science courses, and laboratory courses. Today, changes are being made to better meet the needs of our current and future students.

Changes in the Department faculty, changes in the way the profession views design education, and new requirements for assessment and accreditation necessitated another look at what we were doing with design and why. We examined what we were doing, what was good and what wasn't satisfactory (based in part on feedback from constituents) in the current sequence. In particular, we approached our review based on what our students do and understand well, and not so well, at the end of their undergraduate education. We examined ways to improve the whole design sequence, not just its components. The resulting design sequence is still eight semesters, but components will be introduced or modified to better integrate the many areas (including ABET's a-k criteria) of engineering science and design in our curriculum.

Introduction

Since its inception in the 1960s, Trinity University's Department of Engineering Science has maintained a large number of design-centered courses as part of its engineering core curriculum. The number and nature of the courses have evolved through the past forty years, culminating in the integrated system of eight design courses described in this paper.

Circa 1980, the highlights of the design curriculum included a year-long senior capstone experience, a single project in which all seniors were involved. The freshman and junior classes assisted the seniors, each during one semester. As the faculty in the Department changed, the design curriculum went through a series of revisions in the early and mid-1980s, resulting in an eight-semester sequence, with topic-specific courses in the first three years, and a small group capstone experience in the senior year. [1][2]

Later in the 1980's, more focused goals for the design curriculum resulted in mini-capstone disciplinary courses in the second and third years. These one hour courses were tied to previous disciplinary courses, and introduced not only the design aspects of the disciplines (mechanical, electrical and thermo/fluids) involved, but they also each had some general topics to address (e.g. manufacturability, design of experiments). [3]

In the same period, the Department explored making better connections among the lecture, laboratory and design courses. One outcome was the installation of more design-oriented problems in lecture courses; another, the creation of laboratory experiments that explicitly involved the use of the lab as a design tool, 'gathering information for design.' [4][5]

The middle of the 90s centered around the implementation of new equipment and facilities, while the design curriculum changed in several areas in the last half of the decade as a result of a major curriculum review. Areas pertinent to modern engineering practice were added, statistical approaches moved earlier into the curriculum, and changes were made in the junior year. [7] The 90s also marked another period of faculty changeover, and the need to revisit the design curriculum again became apparent. The existing structure seemed disjointed to new faculty, and evolutionary changes in some of the courses contributed to this disjoint. A fresh look at design was needed.

In 2000, one of the new faculty members suggested implementing structural changes in the senior experience—changes that provided a schedule- or milestone-driven capstone experience. [6] This improved the senior course, but ties between the senior experience and previous design courses needed to be strengthened.

Why Revise the Design Sequence?

The current eight-semester design sequence was instituted in the late 1990's. [7] Since then, constituency feedback and Departmental curriculum assessment provided suggestions for incremental improvements in the design sequence. These improvements were easily implemented on a continuous basis within the context of the current course description. However, a recent revision of our mathematics curriculum for engineering students required a change in course content for the third and fourth design courses, which are offered in the sophomore year. Specifically, a new requirement for Engineering Science students to complete a new probability and statistics course for engineers eliminated the need to continue teaching this material in the design sequence. The elimination of probability and statistics and design of experiments from the third and fourth design course provided an opportunity to add new course material to the design sequence, and to revisit the core of our program with a new corps of faculty.

The Process Used to Revise the Design Sequence

The question was "What new concepts would most benefit our students?" To answer this question, the faculty in Department of Engineering Science conducted a comprehensive review of our eight-semester design sequence from January 2004 to April 2005. The process began by analyzing the feedback from our constituencies. Base on this feedback, faculty members outlined expected outcomes of the design sequence and the expected levels of student expertise for each outcome. This information along with an indication of which design and Engineering Science core curriculum courses addressed these outcomes was recorded during several hour-long department meetings. The product was a spreadsheet containing 49 expected outcome areas, a portion of which is displayed in Figure 1. These expected outcome areas involve skills, knowledge, experience, or exposure.

The first column reflects a weighted average of the eight faculty members' opinions of the expected level of expertise for each outcome. The numeric rubric used to calculate the weighted average is shown at the bottom of Table 1 and includes the following level labels: Master, Apprentice, Novice, and Optional. The weighted averages for the outcomes ranged from 34% (Optional to Novice) to 100% (Master). The second column indicates the degree to which improvement in the outcome was desired. Three asterisks in this column indicate that the outcome requires significant improvement, while the absence of any asterisks indicates little to no need for improvement. The third column lists the 49 outcome areas. The next eight columns represent the eight sequential design courses in the design series. The notation indicates whether the students were taught (T) the outcome or simply exposed (E) to some facet of the outcome and whether any superficial (S) or in-depth (D) applications were required in the course. The last column lists non-design courses in the engineering science curriculum, which also involve the outcome areas.

Expected level of expertise (^)	Desire to improve (*)	Outcome	In which classes is outcome/area addressed? [1]								
			I	II	III	IV	V	VI	VII	VIII	Input Non-Design Course Numbers
100%		Ability to communicate orally (presentations)	ED		ED		ED	ED	TD	TD	
100%	*	Report writing	ED	D	ED		ED	ED	ED	ED	3123, 4126, 4341, 4366, 2359, 4165, 2120, 2164
94%	**	Literature search	ES	E	ES			S	ED	ED	4341, 4366, 2359
94%	**	Past solutions, examples, related problems		E				S	ED	ED	
91%	**	References						ED	ED	ED	
88%	**	Creating models		TD	ES	ES	TD				3123, 4126, 3355, 1313, 2314, 4377, 4177, 3323, 2120, 2164, 2364
94%	**	Using models	ES	TD	ES	TD	TD				3123, 4126, 3355, 3155, 4377, 4177, 3323, 2120, 2164, [illegible]
91%	**	Validating models									3123, 4126, 3155, 4177, [illegible]
94%	**	Ability to analyze set of data, an outcome, etc.	TS	ES	ES				[illegible]	[illegible]	[illegible]
93%	[illegible]	Ability to use design methodol[illegible] r app[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[1]Terms to rate extent outcome is addressed (T,E) and/or applied in class (S,D) [T & E are mutually exclusive; S & D are mutually exclusive]

T	Taught - component of outcome was taught (Marginal to Mastery Skill)
E	Exposure - outcome was discussed, but not in depth (Novice Skill)
S	Superficial application = minimal understanding of outcome was required to apply to a simple, perhaps even guided or group, exercise
D	in-Depth application = ample understanding of outcome was required to apply to substantial exercise

^Expected level of expertise of student graduating from Trinity ES Dept. and entering work force [NOTE: M, A, N, O are mutually exclusive]

M	100%	Master = I can utilize this with little doubt, reassurance, or reference
A	75%	Apprentice = I know I've seen this and understand some of the basic principles… with some refreshing, I could do it again
N	50%	Novice = I recognize this concept and have some appreciation for where it might be useful, but could not perform it
O	25%	Optional = I am unfamiliar with this concept. It is reasonable to expect my employer to provide training if require at my job

*** Desire to improve**

	Little to no indications during assessment for need to improve
*	Some indications in assessment to prompt improvement
**	Substantial indications in assessments to prompt improvement

Figure 1. A section of the expected outcomes areas spreadsheet used to evaluate the current design sequence along with definitions of characters and symbols used in the spreadsheet. The entire spreadsheet includes 49 outcome areas.

Using this spreadsheet as a guide, the faculty then developed an organizational chart (not shown) addressing the following considerations for each outcome: specific details of how the outcome was not fully met, possible mechanisms to improve it, and if appropriate, the optimal time (freshman, sophomore, junior or senior year) in the design sequence that could best integrate improvements considering engineering science course prerequisite. This step was completed during a day-long retreat and several hour-long department meetings. A second spreadsheet showing all engineering science courses, including design courses, in the curriculum and current course content was composed for cross reference during this process (not shown).

Using information from the expected outcomes table, the organizational chart, and the spreadsheet of current engineering course content and sequence, the faculty's next step was to decide exactly what to integrate into the design sequence and how. This step was accomplished during a daylong department retreat and a few hour-long department meetings. To begin, eight large sheets of paper (2'x3') were hung on the wall and labeled Design I through Design VIII. A post-it note was placed on the sheets for each topic currently taught in each design class, establishing the current baseline. As expected outcomes on the list were discussed, additional post-its were placed on the sheets corresponding to design classes in which new content was proposed to be taught. During the first pass through the list, several outcomes were "split" between two courses in the design sequence. Further discussion and negotiation determined the final placement of course content. On several occasions original course content was moved from one course to another. In many cases notes were just made to indicate a desired change in level of emphasis in the class. The ideal scenario was for the student to be taught or exposed to an outcome in one class, with or without application, and then to encounter that outcome in a subsequent class with required application. The repeated exposure to an outcome is believed to increase students' retention of that outcome.

Results

Discussion of the eight-semester design courses naturally evoked discussion of related courses, thereby providing a holistic, rather than isolated, approach to proposed changes. This is reflected in suggestions for changes to core courses as well as design courses. In addition to course changes, it was decided that the Department would create an on-line reference guide containing information that students require for multiple courses. In addition to facilitating dissemination of common information, a single reference source will foster greater continuity between courses. For example, a single design approach model will be agreed upon by all faculty members, posted in the on-line student reference guide, and emphasized in each design course.

The notable changes in course description are shown in Figure 2. The text with strike-through have been removed from the current description in the university Courses of Study Bulletin and the underlined text indicates changes and additions to be implemented in the 2006-2007 academic year. The most dramatic change in the design curriculum was the creation of a yearlong sophomore mini-capstone design experience (ENGR 2181 & 2182) in addition to the yearlong senior capstone design experience (ENGR 4381 & 4382). The sophomore mini-capstone design experience focuses on realistic design constraints, project management, and communication skills, all of which were previously covered in an informal piecemeal fashion throughout the curriculum before the senior design experience. A service learning based project would be an ideal candidate for this course to incorporate realistic design constraints. Other notable additions or increase in emphasis throughout the design course are as follows: time management, consideration of past solutions, multimedia presentations, manufacturability, six-sigma, instrumentation, deterministic vs. probabilistic design, and design journals. These changes in the design curriculum will help current and future students meet the challenges of evolving technology and impacts of globalization as stated in recent evaluations of engineering education. [8]

ENGR 1381 **Engineering Analysis and Design I**

Introduces students to the engineering design process utilizing a competitive design project. Small groups of students conceive, design, build, and test a structure or device to best achieve specified performance criteria under realistic constraints. Emphasis is placed on Computer Aided Design (CAD). Supporting topics include sketching, construction and testing techniques, measurement concepts, data analysis, ~~and~~ communication, and time management.

ENGR 1382 **Engineering Analysis and Design II**

Continues the introduction to engineering design with another interactive team-oriented design project. Emphasis is placed on numerical analysis using computational software. Supporting topics include programming mathematical models of physical systems, and data gathering, analysis, and presentation. Consideration of alternative and past solutions.
Prerequisite: ENGR 1381.

ENGR 2181 **Engineering Design III**

Continues the development of students' design skills through a project emphasizing constraints including: ethics, health and safety, manufacturability, sustainability, economics, the environment, and social and political issues. Supporting topics include project management, literature search and communication skills**.** ~~Builds on the students' background in solid mechanics with the introduction of a competitive mechanical design project. Engineering economics is introduced in support of the project. Other supporting topics include mathematical modeling, sensitivity and uncertainty analysis and statistical concepts.~~ Oral and written reports are required.
Corequisite: ENGR 2314.

ENGR 2182 **Engineering Design IV**

Continuation of ENGR 2181: final design, construction, testing, and evaluation. Engineering economics and life-cycle costs are introduced in support of the project. ~~Continues the development of students' prediction, decision-making, and optimization skills with a project oriented to the statistical design of multi-variable industrial systems. Supporting topics include engineering modeling, problem solving, and industrial design of experiments with related mathematical statics~~. ~~Oral and written reports~~ Multimedia presentations are required.
Prerequisite: ENGR 2181.

ENGR 3181 **Engineering Design V**

Builds on the students' background in electrical engineering with emphasis on the design of a system that may employ circuits, electronics, electromagnetics, and controls. Supporting topics include safety, electrical measurements, component tolerances, specifications, ~~and~~ performance standards, and manufacturability. An introduction to six-sigma concepts. Oral and written reports are required.
Prerequisites: ENGR 2364 and 2164. Corequisite: MATH 3320.

ENGR 3182 **Engineering Design VI**

Builds on the students' background in thermodynamics/fluids with the introduction of a competitive thermal-fluids design project. Supporting topics include thermal-fluids instrumentation and measurements and computerized data acquisition, analysis, and visualization. Application of uncertainty analysis and design of experiments. Introduction to deterministic vs. probabilistic design. Oral and written reports and design journals are required.
Corequisites: ENGR 3323 and 3123.

ENGR 4381 **Engineering Design VII**

A capstone design experience with small groups of students, each group advised by a designated faculty member. Includes the establishment of objectives and criteria, ~~synthesis~~, modeling, analysis and synthesis, ~~safety,~~ and aesthetics for the ~~and~~ preliminary design stages of ~~a different project for~~ each group's project. Projects will involve realistic design constraints such as ethics, health and safety, manufacturability, sustainability, economics, the environment, and social and political issues. ~~Robust product design considerations~~. ~~Formal written and oral presentations~~. Oral and written reports and design journals are required.
Prerequisite: Consent of Department Chair.

ENGR 4382 **Engineering Design VIII**

The capstone experience continued, including ~~covering~~ final design, construction, testing, and evaluation of the projects started in ENGR 4381. ~~Life cycle testing and reliability~~. Oral and written reports and design journals are required. ~~Formal final written report and presentations open to the public~~.
Prerequisite: ENGR 4381 or consent of Department Chair.

Figure 2. Revised design course descriptions, reflecting the aforementioned list of changes.

Conclusions

The process of making the changes in our design curriculum wasn't easy, nor did it happen as quickly as we might have preferred. It was thorough, it was (mostly!) collegial, and we believe it will improve our program and help with assessment and accreditation. It will provide our students with a better view of what an engineering career demands, and it will help them meet the requirements for licensure.

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DIANA D. GLAWE
Dr. Glawe is an assistant professor in the Department of Engineering Science at Trinity University. Her research interests include silica nanostructures, laser-based measurements, and sustainable building. Dr. Glawe is a member of ASEE and the advisor of the Trinity University student chapter of SWE.

J. PAUL GIOLMA
Dr. Giolma is an associate professor in the Department of Engineering Science at Trinity University and a registered professional engineer in the State of Texas. Dr. Giolma has been a member of ASEE since 1981 and is a member of IEEE (Signal Processing and Education Societies), Sigma Xi, Tau Beta Pi and NSPE.