Successes and Failures In Teaching a Freshman-Level Engineering Design and Graphics Course

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Abstract

The author discusses experiences teaching a freshman-level engineering design and graphics course over a two-year span at the DuBois Campus of the Pennsylvania State University. This course is a survey course that covers many diverse topics in limited detail. Due to local circumstances, the instructor prepared the course plan without direct contact with the previous instructor of the course. As a result, the author developed the course based on a previous syllabus, previously used textbooks, his industrial experience, and previous teaching experience with sophomore-level engineering students. Student evaluations of his teaching effectiveness the first year were low. The author believed the major problems did not lie with the overall plan for the course, but rather in some of the details covered, and his overestimation of the capabilities of first semester engineering students. While preparing for and teaching the course a second time, the instructor made modifications in several of the details, provided more guidance to the students during the portions of the course that proved to be problem areas, and approached the course with a better understanding of first semester engineering students. The author believes that these changes resulted in a significant improvement in how well the students learned, evidenced by the students' higher evaluation of the instructor's teaching effectiveness (a 36 percentage point increase). This paper discusses the overall plan for the course. It also discusses the problems experienced the first year, the modifications that were made the second year. Finally it discusses the instructor's enhanced understanding of first semester engineering students.

I. Introduction

The course, Introduction to Engineering Design and Graphics, taught at the Pennsylvania State University, is a broad survey course taught to students with different backgrounds usually in their first semester in college. It covers the following general topics: laboratory practices; mechanical stress, strain and the measurement of strain using a wheatstone bridge; circuit building; engineering design projects; report writing; presentation making; traditional mechanical drawing; and an introduction to word processing, spreadsheets, presentation software, and CAD packages. Structuring and delivering such a course successfully to freshman students is a challenge. Having taught the course over a two-year span, I believe those challenges involve: balancing the breath of the topics with the appropriate level of detail, ushering the students through design projects when they possess almost no technical engineering knowledge, and delivering the entire course in a coherent, integrated package.

To further complicate this process, I created and delivered the course plan the first time as a new faculty member at this university, at a location where these responsibilities are handled by a single person. The previous instructor was unavailable for consultation. Just prior to accepting this teaching position I was a full-time research engineer in industry, but had taught sophomore level engineering mechanics courses at a different institution. At that time, I believed that my industrial and academic experience together with a previously used syllabus for the course would be enough to succeed. As it turned out, despite what I thought was a good plan, the initial offering of the course was a disappointment, both from the standpoint of the students' evaluation of my teaching effectiveness and my own sense of the how the course went. Upon reflection, I made several changes to the course, and the results were substantially improved the second time. Again this was reflected in both the student evaluations and my own satisfaction.

Assessments of teaching such courses have been presented before; for example, Yue[1] assessed a comparable course and reach similar conclusions about design projects as those presented here. In addition, reviews of the entire freshman-year engineering curriculum, which include discussions of such courses have been presented; for example, the work of Craven, Wayne, and Stiller[2].

The purpose of the paper is to discuss the successes and failures associated with teaching this course in the hope that this can benefit others. The remainder of the paper is organized as follows: first generation course plan, delivery of that planned course and lessons learned, second generation plan and successes, and summary.

II. First Generation Plan

The most important portion of my first course plan can be summed up in a single word: integration. It was clear to me that given the breath of the course content, without an overall emphasis on integrating the pieces, the course could come across as four separate and unrelated topics. To understand another important course component, it is necessary to understand how the Penn State University System operates. The Pennsylvania State University is composed of 20 campuses spread out across the entire state. The largest of these, the University Park Campus handles approximately 50% of the incoming engineering freshman. The remaining 50% are distributed at other locations across the state, of which the DuBois campus is one. (The system operates as a single integrated system in almost all respects; however, production and fabrication facilities do not happen to be one of them.) As a result, the implementation of the design projects varies significantly across the system. Given the limitations of the facilities at the DuBois campus, I chose to implement the design phase in the form of two theoretical design projects. By integrating ideas from the laboratory exercises into the design project, the projects also had a practical component.

Relative to the overall course plan, there were two additional considerations. The first was an attempt to eliminate as much of the “black box” approach to engineering instruction as possible. While I accepted treating calculus as a “black box”, I was determined to have the students understand as much else as possible. The second consideration was my lack of understanding of first semester students. My previous experience had been with sophomore level students, and I was not prepared for such sizable differences between the two groups.

III. Delivery and Lessons Learned

As I taught the course the first time, it was apparent that there were some problems with the initial plan and delivery. Fortunately the overall principle of integration was not of concern. Several specific detailed topics, however, were clearly a problem, along with an overestimation of the capabilities of freshman students.

The first and most significant of these problems came with regards to calibration of laboratory equipment. In the first laboratory experiment, the students work with electrical resistance. This exercise includes the measurement of known standard resistors to generate a calibration curve and measurement of other resistors and use the calibration curve in order to better estimate the actual value of the resistance. In general there are two approaches to generating the calibration curve: 1) using a pre-existing curve fitting capability, as exists in many spreadsheet applications, or 2) discussing curve fitting and solving equations for the parameters describing a specific curve fit. I chose the latter approach for several reasons. It would not treat curve fitting as a "black box", and it was a good example for teaching the students how to use spreadsheets to do summations and other mathematical operations. Upon grading the laboratory reports, it was clear that almost none of the students understood the generation and use of the calibration curve, despite the fact that they had not asked questions about the material. On three separate occasions I tried to clear up the confusion with very little success. In the process I learned several quick lessons. First, the details of curve fitting, even without the calculus, were beyond the understanding of the students. Second, by allowing a detail to cause confusion, I had inadvertently obscured the more important issue of the calibration curve and its use. Finally, freshman students are not nearly as resilient as sophomore students. If they become confused about a topic, it is very difficult to regain their full attention. To address these issues in the future I would concentrate on the calibration curve and its use and treat the curve fitting as a "black box".

The second major problem came in the execution of the two design projects. In general this problem was associated with overestimating the students' mathematical and logical reasoning. I understood that they brought no engineering knowledge into the course with them. In response to that fact, I based the theoretical aspects of design projects on the concepts they had gained earlier in the course, namely stress, strain, strain gages, and Wheatstone bridge measurements.

To illustrate the deign project issues, consider the following example. The students have been asked to design a weighting system to determine the height of water in a 6-inch diameter cylindrical tank (this assignment is found in one of our course textbooks by Kallas and Sathianathan[3]). Assume that the group has chosen to use a strain gaged cantilever beam, with a rectangular cross-section, as part of their design. The behavior of such a design would be described by the four equations shown in Table 1.

Equation	Behavior	Parameters
$\varepsilon = C_f V$	Wheatstone Bridge	ε is the strain, C_f is the calibration factor and V is the output voltage
$\sigma = E\varepsilon$	Stress-Strain	E is Young's Modulus, σ is the stress
$\sigma = \frac{6PL}{wt^2}$	Load-Stress	P is the load, L is the length of the beam, w is the beam thickness and t is the beam thickness
$P = W_{other} + \frac{\gamma\pi D^2 h}{4}$	Load-Height of Water	W_{other} is the weight of the load other than the water, γ is the weight density of water, D is the inside diameter of the cylinder, and h is the height of the water

Table 1 – Equations Describing the Behavior of Design

These equations can be used to obtain two valuable relationships. The second, third and fourth equations can be combined to relate strain to the maximum load, if the height of the water is the maximum height of the water. Used with a constraint on the maximum strain, say 0.002 in/in, this provides an equation that can be employed to pick one parameter describing the beam if all the other parameters are chosen. These other choices will be made based up on other considerations, such as cost or availability. This provides the students with a means to find an acceptable design. Another use of the equations is to combine all four to develop a single input-output relationship between the voltage (input) and the height of the water (output). Such a relationship would be critical to the making of a device that provided the operator the desired output (height) given the input available from the Wheatstone bridge (voltage).

I initially overestimated the students' abilities to associate several principles together to come up with overall design equations. Again the students were initially reluctant to ask questions when they were confused. Based on experience with the calibration curve, however, I quickly took a more forceful approach to leading the groups through the design process. This change led to eventual success. This problem proved not to be as serious as the one associated with the calibration cure and curve fitting.

The other lessons learned in teaching the course the first time were detail related. The first of these was related to the example I chose while teaching the students word-processing. It was a cover letter to apply for a summer job. While I though this would be a practical example for the students, it failed to capture their interest. The second of these lessons was the realization that I needed to further emphasize the importance of units in engineering calculations.

Given the problems I encountered teaching the course the first time, I was not surprised the students' evaluation of my performance was lower for this course than the other courses I taught that semester. I had already decided to make several changes to the course, and this feedback reinforced that decision.

IV. Second Generation Plan and Successes

Based on my initial experience, I believed the fundamental idea of the course, specifically integration, was excellent. I chose to make changes in the areas where problems arose the first time I taught the course. The first of these was a change in how I handled the issue of calibration and curve fitting. First, I decided to treat curve fitting as a "black box" and to concentrate more effort on the primary topic of calibration. I augmented the first generation discussion of calibration with a more illustrative example of how and why engineers calibrate. In the measurement laboratory, because the multi-meter is quite accurate, the effect of calibrating the meter, while important, is not very significant. To better demonstrate the principle, I devised and constructed a modified yardstick where calibration would be both important and significant. This also allowed the entire class to work with the same example directly in the computer classroom where we would be using a spreadsheet application to generate the curve fit. The modified yardstick is shown along with a standard yardstick in Figure 1. The standard one is on top, and the modified one is on the bottom. For the example, 7 lines of known length were drawn on the board. A student then came up and measured the 7 lines with the modified yardstick. The class then plotted the data in an EXCEL spreadsheet based and used the curve fitting option in the spreadsheet to generate the calibration curve parameters. Finally the length of an unknown line was estimated by means of a measurement with the modified yardstick and the calibration curve. This calculation was done in EXCEL as well. Figure 2 shows the spreadsheet used to create the calibration curve and also employ it to estimate the length of the unknown line. The actual length of the unknown line was 23 inches, which compares exceedingly well with the estimate of 23.0096 inches. While this approach left the curve fitting as a "black box", the students learned the more important principle of a calibration curve and its application without being confused by secondary detail.

In a related note, I chose to change the word-processing example to include aspects of the calibration curve example. Given the poor reception that my cover letter example had received in my first teaching of the course, I chose to construct a contrived example that integrated with the calibration curve example. In this case the students and I wrote a hypothetical letter to a friend explaining the calibration work. This example was more typical of an engineering report because it included equations and a graph. While this took the idea of integration to almost absurd levels, the students responded to the example very well.

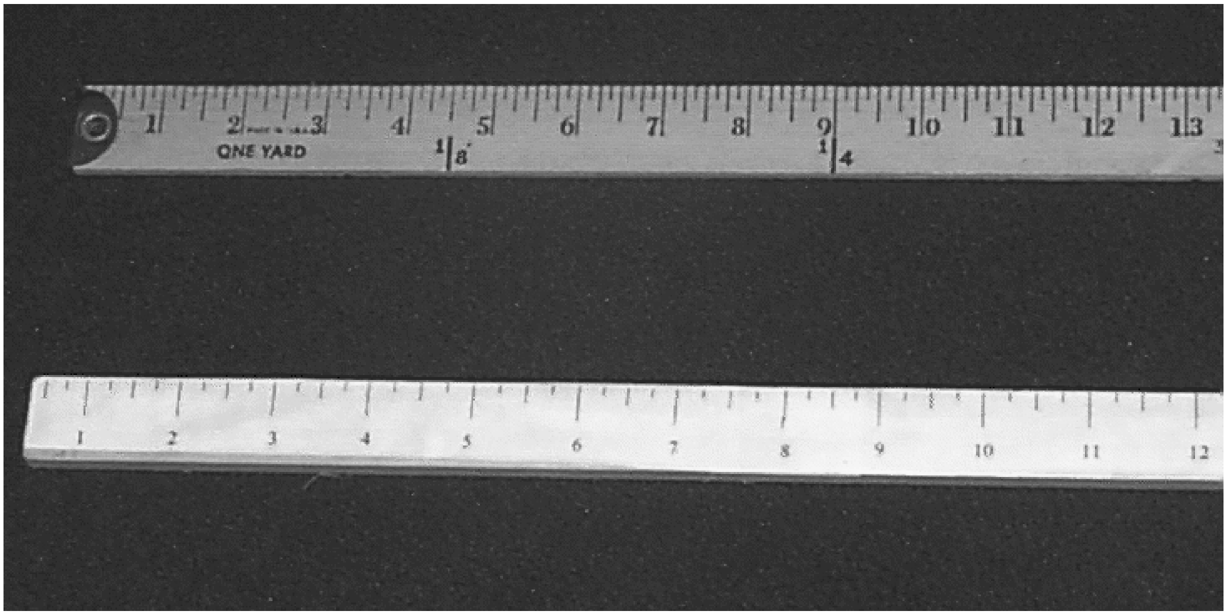

Figure 1. – Custom Yardstick For Calibration Curve

Measurement Example	
known	measured
5	4.8
10	9.3
15	13.5
20	17.7
25	22
30	26.3
35	30.5
Curve Parameters	
m	0.8543
b	0.6429
Use of Curve	
Measured	20.3
Estimated	23.0096

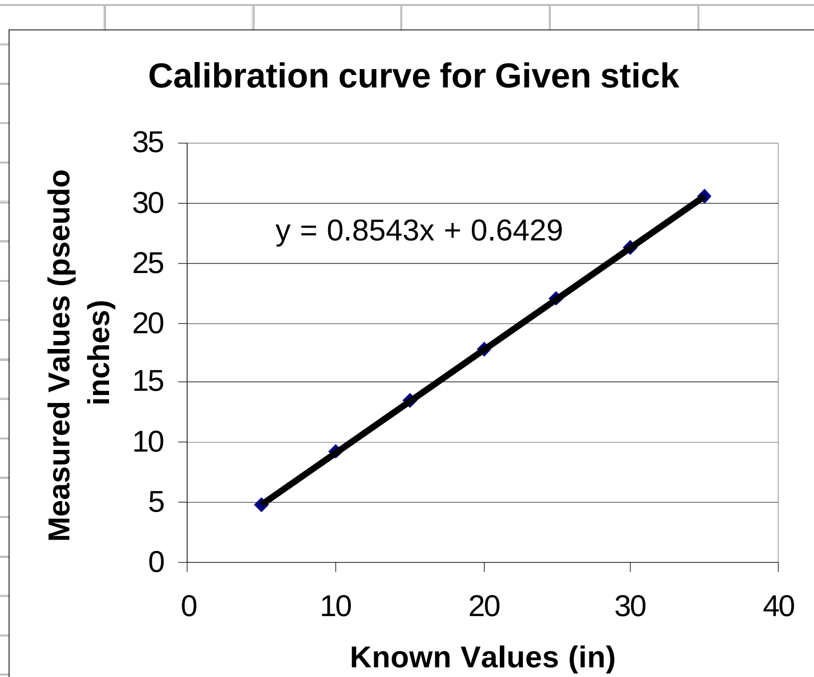

Figure 2. – Spreadsheet Calibration Example

The design projects were more successful the second year because I was able to allow the students to learn without becoming frustrated. I expanded my emphasis on units and worked to develop topic introductions that would capture the students' interest. One example was introducing HTML programming by discussing what has changed and what hasn't changed in engineering in the past 20 years by analogy to Washington Irving's story of Rip Van Winkle. My sense of the success of these changes was quite positive. When the students' evaluation of my teaching effectiveness came back, it confirmed the improvements. The students' evaluation of my effectiveness improved by 36 percentage points. This placed the score in line with the other courses I teach. As a result, I view the second-generation course and its delivery to be a success.

V. Summary

Initial failures and subsequent successes in teaching a freshman-level Introduction to Engineering Design and Graphics have been discussed. The failures stemmed from mistakes in dealing with certain levels of detail and an overestimation of the capabilities of first-semester engineering students. Changes to the course structure and delivery to address these failures have been discussed. These changes have resulted in a significant improvement in the quality of the course. This improvement was apparent to the instructor while teaching the course and also evidenced by students' evaluation of my effectiveness.

Bibliography

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