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Ten Years and Ten Lessons Learned: Design of an Introduction to Engineering Course in a Nascent School of Engineering

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Abstract

This Work in Progress paper reviews the Introduction to Engineering course at Dunwoody College of Technology which serves as a foundation for students enrolled in the electrical engineering, mechanical engineering, software engineering, and industrial engineering technology programs. This paper summarizes some of the lessons learned while developing and reworking an Introduction to Engineering course in a new and growing School of Engineering. One area of particular interest is the merging of two separate courses into a generalized course with learning outcomes that serve the needs of students in all four programs.

The School of Engineering at Dunwoody started in 2011 with a Bachelor completion degree in Industrial Engineering Technology. This program holds classes in the evening to accommodate working adults who completed an Associates of Applied Science degree in a related field which serves as the first two years in the 2 + 2 completion program. In this program a 2-credit course titled Introduction to Engineering was taken in the first semester. In 2016 a traditional Mechanical Engineering program (day courses, more traditional aged students) was added, and a 3-credit course was created which has some similarities to the evening course. Additional offerings of Software Engineering and Electrical Engineering were added in 2017 and 2018 respectively which take the 3-credit version.

One of the authors has taught the day course in fall 2016, spring 2017, fall 2017, fall 2018, and fall 2020. The evening course, which is offered every semester, was primarily taught by adjunct instructors through the early years of the program. The evening program offers the course every semester. Since spring 2018 the evening course has been taught by full-time faculty including the other author.

As the course audience has expanded, the needs of the students have changed. Dunwoody is a school that distinguishes itself as a place where students learn by doing. As such, the daytime offering of the course has always included a design project. Other course content is like offerings at other institutions with a focus on study skills, applying the engineering design process, surveying various engineering disciplines, communication, and teamwork. For the evening students, the primary purpose is to get them to understand the rigor and time commitment required to be successful in the completion program. The overarching goals for the course are threefold: 1. Is engineering the right path for me? 2. Is the discipline I have selected the right choice for me? 3. What career opportunities are available for engineers in my chosen discipline? Since the evening students have less options without starting over, they generally do not explore the second goal as much.

Some additions and changes have been focused on broadening student perspectives and giving students tools to understand the curriculum and increase persistence which in turn improves retention. Both groups have benefited from a Women in Engineering panel, generalized estimation practice such as scoping a problem or developing a calculation based on gross

assumptions, and growing an appreciation for mathematics and its application in engineering curricula.

Changes to the course have been made based on student feedback and instructor observation. In particular, the design project has changed to better achieve the course goals. Conclusions on the content, methods, and activities that most effectively (in our current understanding) serve our student population are also presented.

Background:

In 2011 Dunwoody College of Technology launched a School of Engineering with a bachelor's completion degree in Industrial Engineering Technology which meets in the evening for working adults. These completion degree students have their earlier AAS degree in a technical field (machining, drafting, electronics, etc.) counted toward their BS degree in engineering technology. Part of that curriculum included a two credit "Introduction to Engineering" course. Five years later, a day Mechanical Engineering program joined the School of Engineering, followed by Software Engineering the following year and Electrical Engineering in fall of 2018. The day programs are marketed toward more traditional college-aged students and are engineering (not engineering technology) programs. The day program curricula all include a three credit "Introduction to Engineering" course.

There are some significant differences between the two audiences. The evening, completion degree students tend to be working adults who have made the transition from high school to an associate's degree program, to the working world. The day students pursuing engineering degrees tend to be younger with many coming directly from high school and needing more help balancing life and school while developing as young adults in addition to their formal engineering training. Some students in the engineering programs transfer in from other institutions or from having taken a break. Most day students are pursuing their education full-time and working part time if at all. Many evening students pursue their education part-time while working full-time. Some evening students have families and other commitments in addition to work and school.

The goals for the Introduction to Engineering courses are multifaceted. In the evening program, it serves as a bit of a "weed out" class. Dunwoody has a reputation as a "very good Trades School" which can sometimes be misinterpreted as anyone can earn any degree. Particularly for working adults, one function of the Introduction to Engineering course is to reinforce the effort needed to be successful in the program before students spend too much time and money finding out the hard way. In the day programs it is a course that hopefully answers two big questions: 1) Do I (really) want to be an engineer? 2) Do I want to be this type of engineer?

This paper is structured as ten lessons learned and what we have found for best practices at our institution. The lesson will be a heading with background information and anecdotes provided to reinforce how we developed that practice. For a quick summary, the ten lessons are listed below:

1. Do not have adjuncts teach the cornerstone course
2. If a general course, use a general course code

3. Relate your content to all represented disciplines
4. Give opportunities to "customize" the course to student's interests
5. Standardize credits across offerings
6. Standardize course competencies/learning outcomes across offerings
7. Know your audience
8. Scaffold content around a project
9. Emphasize communication skills
10. Encourage metacognition and reflection

Lesson 1: Do not have adjuncts teach the cornerstone course

As a new program that meets in the evening, most courses in the Industrial Engineering Technology programs were taught by adjunct faculty in the early days of the program. When the day mechanical engineering program started, the string of adjuncts who had taught the evening course were not available to the new full-time day instructor. As a result, the author developed a new, three credit version (per the ME academic plan) of the course with little outside consultation. About a year after the formation of the day version a full-time faculty member took over the evening cornerstone/intro course which resulted in more opportunity for collaboration and sharing of resources between the versions. This change provided good continuity between the introduction course and subsequent courses in the programs. Further, the rigor of the evening course was further developed and used to get students acclimated to an engineering program (as opposed to the associate degree technician level coursework).

Lesson 2: If a general course, use a general course code

Some institutions have two "intro" courses; one for the field of engineering as a whole and a second more directly related to the discipline chosen. Some institutions have only the discipline specific, others have only the general, and still others (though seemingly a dwindling minority) have no introduction/cornerstone class at all. If the course is general in nature, it should have a general course code.

As mentioned earlier, two versions of Introduction to Engineering were offered for several years. There were differences in outcomes and audiences. The evening program had an IENG (Industrial Engineering Technology) course code while the daytime program used a MENG (Mechanical Engineering) course code. This worked fine enough until additional day programs were rolled out. When software engineering students and electrical engineering students saw the course on their schedules there was some initial confusion. The first time with a combined student population the author did not anticipate the perception that the course would be seen as outside the non-MENG students' discipline (as most of the content is of general engineering interest) which led to some difficult moments and mid-course tweaks to provide additional representation of other specific disciplines.

In the last couple of years, we have revised the course and academic plans to use a general engineering course code (ENGR). This reduces the initial consternation for students seeing a course for "another discipline" on their plan of study. Other courses have also benefited from this change and additional course code. For example, Engineering Economics, Engineering

Ethics, Programming, and Mechatronics are under the ENGR course code while previously we had multiple versions or MENG specific course codes for these topics.

Lesson 3: Relate your content to all represented disciplines

This is related to Lesson 2. If your audience is mixed among disciplines find ways to incorporate examples, case studies, field trips, guest speakers, and other connections to each of the represented disciplines. It is easier to sit through a lecture on basic circuits as a mechanical engineer if you know that next week the topic will be forces and mechanical work. Similarly, visiting a potential employer site which employs many or all of the disciplines in the course makes it easier for students to envision how the skills they are developing will interface with those of their peers in another discipline and how all the disciplines work together to develop engineered solutions.

One way that was simple to communicate which content "belongs" to a discipline was to use color codes on the schedule to show what activities/lessons apply to all disciplines (communications, ethics, engineering design process, etc.) and which are more specifically focused on a given discipline (circuits, forces, programming, etc.). In this way it is easy to see that much of the course is general in nature and only about 10% of the course is dedicated to any one discipline (about 30% total).

Lesson 4: Give opportunities to "customize" the course to student's interests

Like lessons 2 and 3 above, allowing students to have some autonomy with some assignments and activities helps keep student interest. Williams [1] discusses the importance of student development in Introduction to Engineering. One way to promote development is allowing students some freedom in their learning which hopefully translates to lifelong learning beyond graduation. The author has assigned interviews of an engineer with a brief report on what was learned. Students are free to select an engineer of their choosing if it is not an immediate relative (mother/father or brother/sister). Students are encouraged to select someone in a field in which they are interested and are reminded this is one of the opportunities to tweak the class to something of their choosing. Other examples are group presentations on a company of the group's choice. The presentation is to give an overview of the company and their business, the type(s) of engineers they employ, and what roles those engineers have. The only stipulation is that groups cannot double up (e.g. no two groups presenting on Tesla or Google).

Lesson 5: Standardize credits across offerings

With the common course code from Lesson 2 we realized we needed to standardize course credits across the two different populations. It makes sense that the students in the day section(s) and the night section(s) earn the same number of credits for a similar experience and amount of work. This change took place during review of all academic plans offered in the School of Engineering, so it was a relatively minor change in the scope of the reworking of all the courses and sequencing of those courses to compose a degree.

Lesson 6: Standardize course competencies/learning outcomes across offerings

Similar to Lesson 5, if the same course is offered in multiple sections the content and outcomes realized should be fairly similar if not uniform. Different instructors may emphasize various aspects of the content and there is academic freedom to employ various approaches to convey that information and evaluate student learning. There was some misalignment initially, but there was a fair bit of similarity as well as noted by Avrithi [2]. The various programs reviewed the outcomes and approaches to teaching the outcomes to ensure that students were adequately prepared for follow-on courses and in the rare cases the Introduction course did not provide the required foundation the follow-on course was adjusted to get the students up to speed. At the conclusion of the course students should have a similar background and be prepared for future coursework in any of the disciplines in which this course code is offered.

One benefit of this change was additional flexibility for students. There have been a small number of students who are in traditional day programs who preferred the evening section and vice versa. With the same course outcomes students can mix and match between the sections offered. This is particularly beneficial for transfer students who may not have started in engineering and have significant transfer credits but have the lion's share of technical coursework remaining. Giving the option to take a technical course (or two!) in the evening to avoid daytime scheduling conflicts with the end goal of graduating on time (or at least sooner) is a value add to prospective transfers.

Some of these unique to Dunwoody but standard within the course experiences are the Women in Engineering panel, estimation techniques (ballpark calculations), dimensional homogeneity, and the importance/applications of calculus. The intent of the Women in Engineering panel is multifold. First, we want to help retain female engineering students by helping them visualize their future selves in various roles as depicted by the panel participants. Second, we want to provide a safe place to begin addressing preconceived notions of what engineering environments are like and bias in our students (and ourselves!) in a safe environment. Third, this is a useful place to begin discussing ethics in design and human-centered design by considering viewpoints of others that differ from the vast majority of our students.

The panel has taken different formats over the years. One form that works well is to have the students sit in groups at tables in a larger room and have the panelist each speak about a specific issue and rotate tables every few minutes. The downside of this approach is that each panelist only gets to speak on one subject (hopefully one she is passionate about) and other panelists are not able to chime in. The advantage is that students must engage with the material as there are only a handful of students with each panelist at a time. Other times the panel has been run in a more traditional format, but the student engagement is up to each individual student. Having students submit potential questions prior to the panel and distilling them down into common themes is one way we have tried to encourage engagement with the material.

Estimation techniques such as developing intuition for what the "answer" might be before you perform a detailed calculation is another piece of our standardized content. Questions like, "What is the volume of a basketball?" "How long did it take me to commute to school?" or "How much load would be on the Golden Gate Bridge if it were packed with pedestrians?" get students thinking about a problem-solving approach, what is known, what pieces of information are missing and what assumptions are reasonable. A few of these types of examples are worked out in class as a group and responses are compared to show how various estimates can wash out over the course of a longer calculation. This approach also serves as a good point to introduce sensitivity analysis and self-assessment of expertise in the area. Understanding what is known/unknown to the student and whether an expert is needed is an important lesson to learn.

Units and dimensional homogeneity are topics common in some introductory engineering curricula. We look at it as a way to fill in some of the gaps in the estimation approach. If we are asked to determine the pressure at some ocean depth, we know we expect a unit of pressure (force divided by area). What other types of dimensions can we combine in a sensical way that would result in a unit of pressure? We might consider the weight of the fluid stacked above that height and realize we need a volume, density, and a depth. While this approach is further developed in a fluid mechanics course later in the mechanical engineering curriculum with the Buckingham Pi theorem, it is worthwhile to bring into the cornerstone class as a "check" to ensure all expected quantities are accounted for. Other disciplines may not have the more rigorous Buckingham Pi coverage, so this may be the only time they encounter unit analysis.

As engineering students understanding the ***why*** of calculus is often difficult as the mathematical concepts are taught by non-engineers who often enjoy math for its own sake and beauty. Engineering students on the other hand want to see how this tool helps them solve problems and apply engineering science to design. In our courses, we briefly spend time connecting numerical integration to estimating areas. Numerical integration combined with dimensional analysis is a powerful tool allowing us to solve important engineering questions such as how electrical charge is stored in a capacitor, strain energy of a deformed material, or how to compute moments of inertia for non-standard shapes.

One instructor has a lesson on "how to integrate a potato" which is entertaining, enlightening, and memorable as it is something the students can visualize and relate to their everyday lives. This visual representation is beneficial to students to help keep the big picture in mind as they go through the various mathematical derivations and proofs to unlock these powerful tools. The applications are motivation to keep pressing on in their math and science studies.

Part of this connection with the mathematical world is made through use of Microsoft Excel. Depending on student backgrounds, this may be the first time they have encountered Excel which is likely the most used piece of software used by engineers in practice. We spend several weeks introducing basic functions in Excel and how to use it as a problem-solving tool.

Lesson 7: Know your audience

As is attributed to multiple Greek philosophers, "Know thyself" or perhaps better said, "Know thy program." What is the unique flavor of your institution, your faculty, and your students? What is the driving motivation for your students to attend your institution? What things should students take away from their first (or one of their first) engineering courses? As Rabb et al. note [3], the program should be relevant to the industry in the region. Similarly, the Introduction to Engineering experience should be relevant to your students, your institution, and your faculty.

As ABET [4] would say, your constituencies should inform the development of your program and your course.

At Dunwoody College of Technology, we are all about hands-on, applied learning. Our students may not be well suited to large lecture halls and unending theoretical derivations. There is still a place for a strong theoretical underpinning in our engineering curricula, however, particularly in a first course our students want to know what they are getting into; what to expect; how to function in this program; and what they will do.

As stated earlier, our day program students tend to be more traditional and thus we spend some time discussing the transition to college from high school. Our evening program students tend to be older working adults. They need to understand how this program varies from other educational experiences they have had and how to function appropriately while balancing work, social, and sometimes familial responsibilities.

With this background, we use different projects in our different sections. In the day program we develop group projects that utilize skills from each of the represented disciplines (see Lesson 3!) with some class time to organize work but much of the work occurs outside of class. In the evening program, there is more difficulty in coordinating schedules outside of class time and thus the project is more focused and assigned individually. The students still apply the lessons they've learned earlier in the course but to a different application in a different (individual) setting.

A further difference between the two groups of students (and possibly students at other institutions in general) is that the evening students are already in a career and looking to get a degree to advance in that field. The day students are less familiar with the engineering employment outlook. During the day offerings we find ways to interact with possible fields. One way is the company presentation assignment which was previously mentioned. During the presentations from other groups students are required to jot some notes into a table. For each company they are to write something they found compelling or that they think they would like about working at that entity as well as something they view as a detriment to their own career goals. These company presentations are also fair game on the final exam and students generally pay careful attention and make well-reasoned inferences from their classmates' presentations.

Another aspect of the day program is to take field trips to company facilities that employ a variety of engineers. Past field trips have included a metrology equipment manufacturer, an automation company, a bicycle design firm, a power plant, a construction site, a building system room (designed by a local A&E firm), a 3-D scanning company, and others. The purposes of these trips are to get students exposed to roles and fields they may not have considered in the past. For example, software engineering students have infrequently thought about all the aspects that go into real-time electricity generation, pricing, and delivery though there is a growing industry around this aspect (and recent events in Texas have brought it into the public sight). This may not be feasible in a large section in a more traditional program, but it is one thing that makes the Dunwoody College of Technology programs "Dunwoody." The evening offering has some of this built in as each student has a different background. Students are encouraged to share their perspectives and applications of course content in their workplaces. When those conversations occur other students take note and the faculty member is given a bit of a reprieve in the lecture. More traditional students taking the evening offering absorb some of this by osmosis.

Lesson 8: Scaffold content around a project

The two types of projects were discussed briefly in Lesson 7 above. In the day program we have found it beneficial to assign the project to a group of various majors. Like the approach presented by Robinson et al [5] the project is structured with milestone deliverables submitted throughout the course of the semester. A separate paper by Aurand and Walls of Dunwoody details a recent project experience in the day offering of Introduction to Engineering.

We have also found the project helps with organizing the technical content of the course as one of the goals for the course is for students to understand the different disciplines, what they do, and how they work together to deliver results for their employers and/or customers. With the project, this is a natural outgrowth as a carefully designed project requires approximately equal contributions from each discipline and students can dive deeper into these areas while peer teaching other group members the basics of the discipline they have chosen.

The technical content in the course is also more relevant to other group members as they see the immediate application to the project at hand. Class examples and activities can be modified from the actual project to build up to the full implementation in the project. Homework submissions on the content are individual but show the relevance to the project and future coursework in those disciplines. We have found that as students experience some of what their peers are pursuing, they develop a greater respect and ability to collaborate with one another.

Lesson 9: Emphasize communication skills

Engineers have a stereotype of being introverts who cannot explain their ideas to normal people. In our courses we emphasize the importance of being able to clearly communicate with other engineers, customers who may not be as technical, managers and other decision-makers, and the general public. You could have the most brilliant idea in the world but if you cannot convince others to buy into your business or purchase your final product the idea is nearly worthless.

Bayles [6] describes the importance of engineering communication within the design project. Our students author several reports of varying lengths and formality. Examples of these include the engineer interview report, field trip reports, guest speaker reflections, and the formal design report for the project. There is also a fair bit of oral communication. We have discussed the company presentations, but there are also presentations associated with the project and an impromptu speech occurs occasionally. Some of the assignments also include graphical communication with 3D modeling or hand sketches to show how various components or parts work together to accomplish a process.

Lesson 10: Encourage metacognition and reflection

As stated above, one of the primary goals of the course is to determine if engineering and the discipline selected is the correct fit for the student. Making this evaluation is something only the student can do. As noted by other researchers and educators [7, 8] metacognition and reflection are valuable tools in developing one's understanding of oneself and internalizing learning. While many of the assignments encourage reflection and evaluation, we also point students to other resources to help them think about themselves as engineers. We have found the Coursera MOOC "Learning How to Learn" [9] particularly helpful in addition to other shorter exercises. Many of these resources are not required as part of the course itself but are encouraged for further reflection and success in subsequent coursework.

Conclusion: 10 years+ since the initial version

After learning these lessons over the last ten years our Introduction to Engineering courses look much different than the original incarnations. We have combined content and outcomes from two different course codes into a single course with the same general engineering course code. We have developed projects that meet our students where they are and challenge them to apply what they learn in the course while providing structure for scaffolding course content. Our students are encouraged to engage thoughtfully with the material and reflect on what they want their careers to look like so they can engage in "the better performance of life's duties," as Dunwoody himself wrote in his will [10]. There is still flexibility to teach the outcomes in unique ways informed by the faculty member teaching and the students taking the course.

None of us knows what the future will bring ten years from now, but we hope that our engineering curricula continue to grow and evolve to meet the needs of the industries we serve in our region and beyond. We believe these lessons, and the spirit of continuous improvement that led to them, will serve us well as we continue training future engineers to solve the problems facing us as a society.

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