The Report Committee for Mathew Robert Deram
Certifies that this is the approved version of the following report:

Increasing Retention Among First-year Engineering Students Through a Hands-on Calculus Module

APPROVED BY
SUPERVISING COMMITTEE:

Supervisor: ______________________________
Richard Crawford

____
Jill Marshall

Increasing Retention Among First-year Engineering Students Through a Hands-on Calculus Module

by

Mathew Robert Deram, B.A.

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Dedication

This work is dedicated to my wife, Nora.

Without her love and support this would not have been possible.

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A special thanks to Starbucks for providing me with coffee, air conditioning, and more coffee as I wrote this report.

Abstract

Increasing Retention Among First-year Engineering Students Through a Hands-on Calculus Module

Mathew Robert Deram, M.A.
The University of Texas at Austin, 2015

Supervisor: Richard H. Crawford

To increase understanding and accessibility of the field of engineering by the public, it is in the interest of engineering programs at the university level to increase retention levels of engineering students, with a higher priority given to underrepresented groups of students. Some universities report that many first-year engineering students leave engineering programs not because of the difficulty of the engineering classes, but because of the difficulty of the prerequisite or corequisite advanced calculus classes. These classes are often taught through mathematics departments and incorporate little to no engineering context. The goal of the Science, Technology, Engineering, and Mathematics Talent Expansion Program at The University of Texas at Austin is to develop and incorporate engineering modules into the calculus course sequence so that engineering students will have opportunities to directly apply what they are learning in calculus to engineering topics. In this report we discuss the process for selecting a calculus topic that is historically challenging for students—solids of revolution—and the creation of an engineering module to help students better understand how calculus is applicable to this topic. The module will center on the engineering design process and is appropriate for first-year engineering students enrolled in calculus I or II, or its equivalent. This module was submitted to current graduate engineering students to obtain feedback. The results are then discussed and suggestion made to improve its efficacy in a calculus class for engineering students.

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Chapter 1: Introduction

Problem Statement

The question of what engineering is and what engineers do is often muddled in public misperception, stereotypes, and the complicated interplay between mathematics, science, and technology. Public opinion suggests that most people simply do not know what engineers do or what their role is in society. A significant proportion of the public views engineering as applied science rather than its own distinct field (Vincenti, 1990, p. 3). Unfortunately, this public perception is largely based on the stereotypes that are associated with most engineers. When students were asked to name engineers that they knew, most students could only name men (National Academy of Engineering, 2008, p. 58). To address the underrepresentation of women and minorities in engineering, one can change how engineering is perceived and make it more accessible to a wider range of people. A pragmatic way to do this is to incorporate methods of improving retention of female and ethnically minority students in engineering programs (Owusu, 2006, p. 210).

There have been many attempts—each with varying success rates—to improve retention of first-year engineering students at many colleges and universities across the globe. At The University of Texas at Austin, engineering faculty have noticed a trend amongst engineering students to withdraw from engineering majors because of the difficulty of the corequisite calculus courses (Allen, n.d.). These classes are difficult for many students not necessarily because of the content, but because of the lack of engineering context. Students learn myriad calculus concepts and skills with little to no opportunity in class to apply them to engineering situations.

Efforts to mitigate the loss of students in UT's engineering programs have been carried out in conjunction with the Science, Technology, Engineering, and Mathematics Talent Expansion Program ("Science, Technology, Engineering, and Mathematics," n.d.). This program, funded by National Science Foundation (NSF) grant 11550, aims to address high dropout rates among freshman engineering students ("Science, Technology, Engineering, and Mathematics," n.d.). The STEP program seeks to mitigate this effect by providing students opportunities, in the form of teaching modules, to apply relevant mathematics to engineering scenarios. My goal is to add to this program by identifying an area of calculus that students traditionally struggle with and then create a module to embed this concept into an engineering design challenge.

PURPOSE STATEMENT

The main focus of my project will be to develop and test an engineering module within the context of a first-year calculus class. I will target mathematics that is traditionally challenging for calculus I and calculus II students, such as calculating the volume of solids of revolution. The module will serve two purposes. First, students will see how mathematics fits into the engineering design process as a tool, and second, students will better understand the specific mathematics skills better. Before the students work on the module, I will pre-teach the requisite mathematical skills so that the mathematics itself is not new. The students in question will be engineering students enrolled in first-year calculus classes. Since most of these students will be taking their formal engineering classes, they will also learn about the engineering design process.

The time is ripe for a change in engineering education. Our population is changing, meaning engineering programs must seek out students from non-traditional backgrounds to pursue engineering. There is strong evidence that teaching engineering in the context of solving problems to help other people, the community, and the environment resonates more with students than simply engineering as a way to apply difficult mathematics and science concepts. Engineering programs should reconsider how they prepare students to be engineers. Many engineering students leave engineering majors because of the difficulties and lack of context in the required advanced mathematics classes. To change this, we can work to intentionally incorporate modules to more effectively teach mathematics skills in the context of engineering problem solving. Using effective tools such as flipped classrooms and active learning strategies can increase students' sense of meaning and purpose in learning challenging mathematics with the hope that they will be more likely to stay in engineering.

Chapter 2: Review of Literature

Public Perception of Engineering

The question of what engineering is and what engineers do is often muddled in public misperception, stereotypes, and the complicated interplay between mathematics, science, and technology. In public polls, engineers have been rated below firefighters, scientists, teachers, priests, and farmers as having "very great prestige" (Pearson, "Changing the Conversation", p. 19). People significantly think—at a ratio of six to one—that scientists are more concerned than engineers with saving lives (National Academy of Engineering, 2008, p. 18). Engineers are less likely than scientists to appear to be caring about the community or sensitive to societal concerns (National Academy of Engineering, 2008, p. 18). Engineers, "by some occasionally dramatic but probably intellectually uninteresting process" use scientific knowledge to make "material artifacts" (Vincenti, 1990, p. 3). From these general stereotypes one can conclude that the public's notion of engineering is one of applied science rather than its own distinct field (Vincenti, 1990, p. 3).

This public perception is augmented by the stereotypes that are associated with most engineers. When students were asked to name engineers that they knew, most students could only name men (National Academy of Engineering, 2008, p. 58). This is in part due to the underrepresentation of women in engineering; though half of the population is female, only 20.5% of engineering degree-holders and 11.0% of people employed as engineers are female (National Academy of Engineering, 2008, p. 22). This disparity is also observed among minorities, where only 3.1% of engineers are African American and

4.9% are Hispanic (National Academy of Engineering, 2008, p. 22). This imbalance is important because by 2050, nearly half of the U.S. population will be non-White (National Academy of Engineering, 2008, p. 21, Owusu, 2006, p. 210). As the population's ethnic makeup changes, both industry and academic institutions will need to consider non-traditional (i.e. non-white, non-male) sources of engineering labor (Owusu, 2006, p. 210). To change public perceptions of engineering, engineering will have to be redefined to be more accessible, understandable, and applicable to a wider range of people. A pragmatic way one can do this is to come up with a new model of engineering to improve retention of female and ethnically minority students in engineering programs (Owusu, 2006, p. 210).

This means changing the way engineering is talked about. As mentioned above, most people think that engineers simply do applied science (Vincenti, 1990, p. 3). Students who pursue engineering often hear messages such as "an engineering education is a sound basis for a career", "engineering offers challenges, excitement, opportunities, and satisfaction", and "engineering is worthwhile, challenging, fun, and within reach" (National Academy of Engineering, 2008, p. 42). These statements, however, do not make reference to the rigors that engineering students face at the undergraduate level. Engineers, according to public opinion, have highly developed skill sets in mathematics and sciences and do work to improve the quality of life (National Academy of Engineering, 2008, p. 42). Public opinion can be changed by focusing not on how studying mathematics and science make people good engineers, but that engineers are necessary for a functioning and progressing society, they have answers or can find them, they make things happen, and they can connect creativity and practicality (National Academy of Engineering, 2008, p. 43).

Changing public perceptions of engineering can occur, among other places, in K-12 education. A significant percentage—nearly one fifth—of American teenagers have no idea about engineering's impact on the world (Scherrer, 2013, p. 38). However, more teens, including females, became interested in engineering simply by learning examples of what engineers do and what opportunities exist for them (Scherrer, 2013, p. 38). Because a majority of students, especially women and minority students, enjoy helping others or the environment over mathematics/science, it seems logical to highlight the fact that a big part of engineering is to help others (Scherrer, 2013, p. 43). Instead of focusing on the notion that people who enjoy mathematics (only 22% of students surveyed) will enjoy engineering, it seems that more students will be interested in engineering if it is presented in the context of helping others (Scherrer, 2013, p. 43). When students participated in projects that highlight environmental engineering and opportunities to better the quality of life for others, they became significantly more interested in engineering. They also realized that being an engineer was a profession that fit their interests in using mathematics and science to help people (Scherrer, 2013, p. 41).

RETENTION OF ENGINEERING STUDENTS AT THE UNIVERSITY LEVEL

While at the K-12 level there is more outreach to students to help change their perceptions of engineering, university engineering programs are farther away from changing the sequence of courses and topics. While these classes might "prepare" students for engineering, they do little to change the perception that only the academically elite can become engineers. At The University of Texas at Austin, for example, freshmen students must take 8 hours of calculus, 7 hours of science, and 6 hours of engineering classes (http://www.engr.utexas.edu/undergraduate/ programs). This trend of advanced mathematics, science, and technical classes continues over the course of the entire degree program, with room for only a few non-engineering electives. While positive correlations between completing advanced mathematics and successful engineering might be substantiated, we know from above that many students who are interested in being engineers do not enjoy mathematics and science. Even if students enter engineering programs with the motivation of helping people, their communities, or the environment, they are instead confronted with four years of intense mathematics and science and ostensibly little opportunity for practical applications of these topics. Instead of being able to see how the seemingly endless list of mathematics skills is applicable to real world scenarios, many of these students become frustrated and drop out of the engineering program. Whether or not these students would have made good engineers in the first place remains unseen; however, using advanced mathematics classes as a "gatekeeper" or "weed-out class" is not likely to increase the diversity and interest of students pursuing engineering. This problem of freshmen retention in engineering can be observed at many colleges and universities both in the US and around the world.

Many other colleges and universities have noticed that freshmen engineering programs have low retention rates, and many engineering departments have tried different ways of increasing this retention. At West Virginia University's College of Engineering, faculty suspected that mathematics courses might be linked to high dropout rates among freshmen engineering students. They had come to the "consensus that mathematics is the largest stumbling block causing drop-out in the freshmen year" (Venable, McConnell, & Stiller, 1995, p. 3c1.23). Thus the faculty developed new courses that integrated computer applications, mathematics tutorials, and design projects. In these new courses, which met four times per week, one of the classes was set aside for mathematics skills. Students could ask questions about specific mathematics skills that were used on the remaining project days. From the instructors' points of view, the implementation of this program went very well; however, this did not produce strong results among students. Ten percent of students dropped before midterms, and only 40% completed requirements for admission to an engineering major at the end of second semester (Venable, McConnell, & Stiller, 1995, p. 3c1.25). Though this "instructional improvement" project was not rigorous to be counted as "educational research", the results indicate that simply adding extra mathematics skills practice might not be enough to sufficiently support freshmen engineering students (Venable, McConnell, & Stiller, 1995, p. 3c1.26).

Other universities have found different ways of dealing with inadequate prerequisite mathematics skills. Victoria University of Wellington, New Zealand had specific issues with freshman engineering students that seemed to stem from the habits that students had developed in primary and secondary school, where students could pick and choose different classes that interested them, rather than a standard curriculum of courses (Carnegie, 2013, p. 62). Furthermore, the minimum passing grade is 50%, so many freshmen enter engineering without having learned any integration or differentiation in their coursework and, in the worst case scenario, having only 50% mastery over the requisite mathematical skills. In their words,

> NCEA permits students to re-sit failed assessment items. Hence our Engineering programme is enrolling students from a secondary school assessment scheme that does not require students to learn a subject in its entirety, students who believe they can just pick which parts they want to learn, students who believe that studying for tests is not vital since a re-sit is expected (but of course not provided), and students who have gained credits at the Achieved-level but who are not actually capable of understanding first year university mathematics. These all pose challenges when we endeavor to retain them in our Engineering Programme. (Carnegie, 2013, p. 62)

The retention solutions that Victoria University of Wellington used mostly had to do with fostering a sense of community amongst the students rather than mathematics skills remediation. They implemented a Peer Assisted Student Support (PASS) program for peer tutoring (Carnegie, 2013, p. 64). While at first only 1% of eligible students used the program, a year later, this increased to 60% as a result of better educating the students as to the benefits of peer tutoring and seeking help (Carnegie, 2013, p. 65). Upon further surveys and interviews, the university discovered that their engineering students did not feel that they belonged to an engineering culture (Carnegie, 2013, p. 65). Therefore they gave some attention to engineering culture by creating the Victoria Student Engineering Club and arranging engineering field trips, Local Area Network (LAN) parties, paintball events, seminars, etc. (Carnegie, 2013, p. 65) In classes, students worked together to construct a robot, the act of which provided significant motivation for students throughout the course and a real sense of satisfaction at the conclusion (Carnegie, 2013, p. 65).

From this program, the effects of a few different interventions can be observed. First, the PASS program was only successful after students had begun to feel a sense of community amongst their peers. Second, students had the opportunity to work with each other on a common project that was not only interesting to students, but also had practical applications. Students could apply the mathematics and science they knew in a collaborative environment, and feel that they had accomplished something meaningful at the end. University professors felt that this was effective at helping students connect the importance of their learning to their lives. Third, researchers noted that among students, "peer influence is one of the most significant factors in a student determining where they will go for tertiary study" (Carnegie, 2013, p. 65). So while the mathematics interventions in the PASS program were somewhat successful, it appears that a sense of student community was paramount to its success.

Other university programs have seen similar successes for similar reasons. For example, at the University of Wisconsin at Madison, engineering students embarked on an engineering project to design, prototype, and build wheelchair access for a nearby historical site. Of the sixty-four students who completed this class, fifty-three (83%) were still interested in engineering upon its completion (Woolston, Shook, & Wilson, 1995, p. 3a3.4). This was higher than the historical 45% retention rate observed in previous years (Woolston, Shook, & Wilson, 1995, p. 3a3.3). While being "interested in engineering" does not necessarily guarantee higher retention, this project supports the notion that students will pursue engineering to a greater extent if they can actively use it to help others and the community. Most of the students in post-class interviews said that they appreciate the teamwork opportunities and involvement of engineering faculty. One student remarked, "It kind of makes you feel like you have a place here" (Woolston, Shook, & Wilson, 1995, p. 3a3.4), echoing the strong effect of having a sense of community amongst engineering students.

At The University of Texas at Austin (UT Austin), engineering faculty have noticed a similar trend amongst engineering students. At UT, freshman engineering students take advanced level mathematics courses that are ostensibly designed to prepare them for the rigors to come. These classes, however, are difficult for many first-semester college students, and many drop out of the engineering sequence because of it. These dropouts are usually associated with Math 408C and Math 408D, the multi-variable calculus and sequences and series courses (Allen, n.d.).

Because of the challenges of these courses, some students take an optional General Engineering (GE) course to help them with the math. The experience in this course has been on the whole quite positive. In this course, some of the mathematics problems are presented with engineering contexts, which allows students to see how the mathematics they are learning applies to their major. This has helped to improve student retention among freshmen engineering students (Allen, n.d.).

In addition to the GE courses, the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP), funded by the National Science Foundation (NSF) aims to address high dropout rates among freshman engineering students ("Science, Technology, Engineering, and Mathematics," n.d.). The STEP program seeks to mitigate this effect by providing students opportunities, in the form of teaching modules, to apply relevant mathematics to engineering scenarios.

FLIPPED CLASSROOM

Part of the efficacy of the teaching modules lies in their delivery. The modules consist of two parts: a short series of online video lectures to cover the requisite mathematics skills, and an in-class activity where students work in small groups to solve a simulated real-world problem requiring the use of the mathematics/science skills they learned in the video.

There is strong evidence that the use of online videos in a "flipped classroom" environment to deliver instructional material is more effective than traditional lecture-based methods. Traditional methods of instruction assume several behavioral learning philosophies and can be described as follows:

> Since the subject-matter as well as standards of proper conduct are handed down from the past, the attitude of pupils must, upon the whole, be one of docility, receptivity, and obedience. Books, especially textbooks, are the chief representatives of the lore and wisdom of the past, while teachers are the organs through which pupils are brought into effective connection with the material. Teachers are the agents through which knowledge and skills are communicated and rules of conduct enforced (Dewey, 1998, p. 3).

This method of instruction assumes several behavioral learning philosophies. For one, it assumes the *tabula rasa* ("docility") model of students' minds; all a teacher need do is spew forth knowledge, and the students will subsequently absorb ("receptivity") this knowledge and be able to regurgitate it on demand (“obedience”). This “transmittal model” of teaching “assumes that the student’s brain is like an empty container into which the professor pours knowledge” (King, 1993, p. 30). Students are passive, rather than active, learners, and the teacher assumes a dominant, “sage on the stage” role (King, 1993, p. 30). This behavioral model of students learning has been replaced by both a constructivist and a situative view of learning. In these newer perspectives, students take more of an active role in the learning process, “participating and thinking and discussing ideas while making meaning for themselves” (King, 1993, p. 30).

In a flipped classroom environment, students come to class already having received some previous instruction. This allows more face-to-face time for implementing active learning strategies such as “think-pair-share”, “concept mapping”, and “problem posing”, all of which can be implemented to engage students in the material (King, 1993, p. 31). Central to the flipped classroom model is to use class time to develop deeper cognitive connections with the material and also to build a community of student collaboration and problem solving. This falls more in line with the situative perspective of learning, as students are engaged in “meaningful participation in a community of practice,” (Johri et al., 2011, p. 155). As mentioned above, students are more likely to continue to be interested in engineering if they feel a sense of community and purpose in their learning. Using a flipped classroom allows for the establishment of this community by increasing the time that teachers and students are able to spend on design projects rather than direct instruction or remediation.

There is also strong evidence that students who learn via flipped classrooms learn and understand the actual content and skills better than their lectured counterparts. To justify this we turn to a study of an undergraduate introductory biology course at California Lutheran University. In this experiment, two groups of students were taught simultaneously, with one group "taught in a long-established, traditional manner, with lectures delivered during class, readings assigned in a textbook, and access to lecture graphics/slides provided via the online syllabus" (Marcey & Brint, 2012, p. 1). The other group was taught using a flipped classroom model consisting of online *cinelectures*, called CLIC (Cinematic Lectures and Inverted Classes), and "active learning assignments" in class (Marcey & Brint, 2012, p. 1). During the first half of the semester, statistically significant differences in quiz and test scores were observed between the two groups, with the flipped group performing better (see Figure 1).

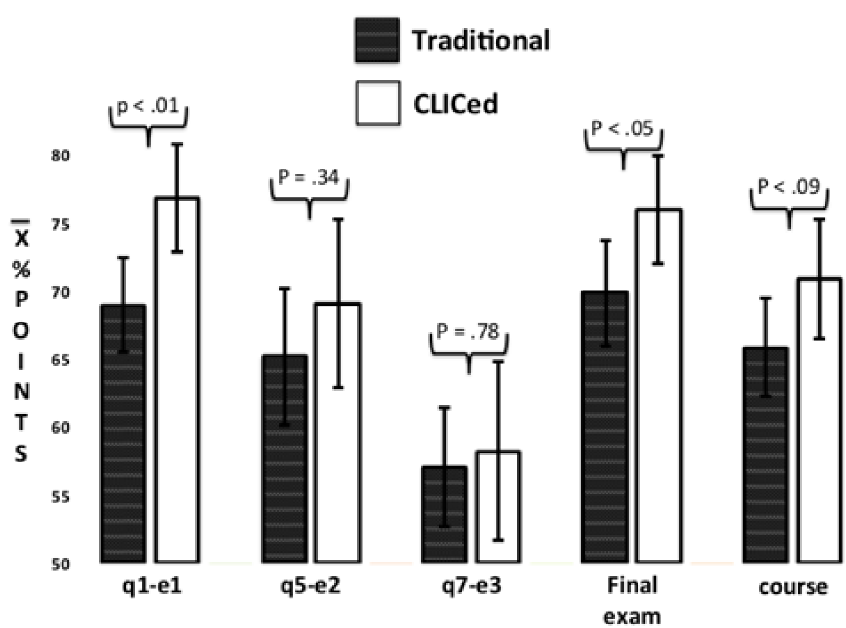

Figure 1: Quizzes and exam results for traditional v. flipped classrooms

Figure 1 illustrates

> [The] mean number of percentage of points available on quizzes and examinations for the traditional and CLICed sections, plotted as a function of semester timepoints. Timepoints are defined by quiz 1 – exam 1 (q1-e1), quiz 5 – exam 2 (q5-e2), quiz 7 – exam 3 (q7-e3), final exam, and course total. P values are unpaired student t tests probabilities, df=46. Shaded bars = traditional section, unshaded bars = CLICed sections. Error bars are 95% confidence intervals. (Marcey & Brint, 2012, p. 5)

As the semester progressed, however, these differences in quiz scores diminished due to the fact that "3/4 of the students in the traditional class had learned of the cinelectures at this time and had added viewing of these to their study" (Marcey & Brint, 2012, p. 5). This unintended occurrence ended up being valuable as it added a control to the experiment; "there was no apparent difference in the comprehension ability between the sections" (Marcey & Brint, 2012, p. 5). This finding is paramount to the validity of flipped classroom's success in the classroom. When examining the quiz scores, the traditional group gradually matched the scores of the CLIC group. Presumably the traditional group was still being given in-class lectures at this point, so they were receiving the benefits of watching the videos outside of class, *not* the in-class activities. Thus, the videos on their own did have an effect independent of the associated in-class activities. Furthermore, there is some evidence that the in-class active learning strategies have an independent effect, since the final exam scores and course scores are higher for the CLIC group at the $p = .1$ significance level. While this might not be significant, it demonstrates that both aspects of flipped classroom, the outside videos and in-class activities, are significantly contributing to student learning as measured by the same metric.

In addition to the academic benefits of using flipped classroom, these students also prefer the CLIC classes to traditional classes. Students who were in the flipped group had a more positive outlook on the course (see Figure 2). The CLIC classes offered students a version of the material that they thought was more "clearly explained" than the traditional version, demonstrating the effectiveness of a video lecture over an in-class lecture (Marcey & Brint, 2012, p. 7). Students felt that class activities were more appropriate and that there was a better atmosphere for participation, thus allowing students to better work together and put the material into context. These data support the quantitative differences in scores between the two groups of students.

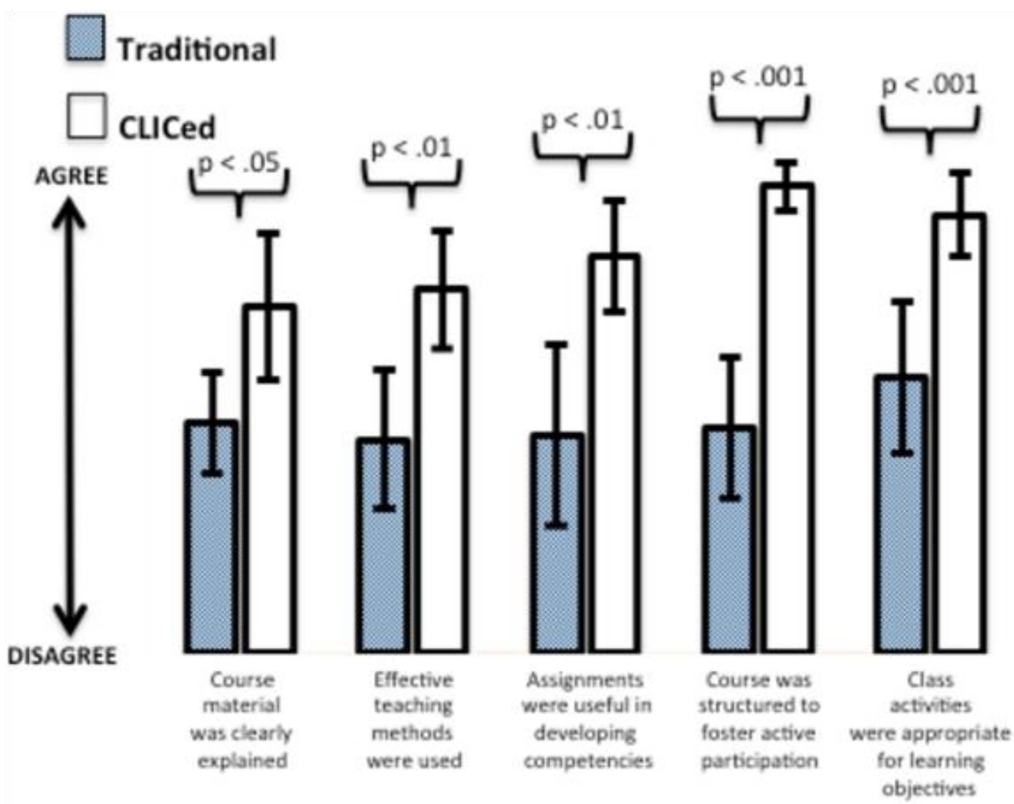

Figure 2: Student responses to traditional and flipped classroom sections

Figure 2 details how

> Student responses to the traditional and CLICed sections rated by the degree to which they agree or disagree with five statements regarding course pedagogy. P values are unpaired student t tests probabilities, df=32. Shaded bars = traditional section, unshaded bars = CLICed section. Error bars are 95% confidence intervals. (Marcey & Brint, 2012, p. 7)

For a quantitative look at how students perform in a traditional sequenced class after taking a flipped class, we turn to a Calculus I course at Lamar University. A group of students took a flipped version of Calculus I during fall 2006, and another group took a non-hybrid version of Calculus I. When comparing the two groups' performance in the traditional Calculus II during the spring, the hybrid group of 40 students had an average grade of 2.25, whereas the other group of 140 students had an average of 1.65. The average grade was obtained by the standard GPA scale; A=4, B=3, C=2, D=1, All other grades = 0 (Maesumi, 2010). Maesumi also identifies some possible explanations for this difference including "higher time requirement [for the hybrid class]", "statistical fluctuation... [in] student backgrounds", placebo effect, and "class participation" (Maesumi, 2010). The in-class portion of this hybrid class involved class discussion and student presentations of solutions to problems. This holds with the proposition that flipped classroom can raise student achievement by more easily integrating active learning activities during class time.

Engineering physics and computer science professors at the University of Wisconsin at Madison created the eTEACH program, a web-based streaming video repository where students can watch lectures outside of class. The engineering physics and computer science professors involved in the eTEACH program realized that "face-to-face time is essentially wasted" if students do not ask any questions during class, "as is all too often the case during lectures in large courses, particularly in science and mathematics-based disciplines" (Foertsch, Moses, Strikwerda, & Litzkow, 2002, p. 267). Instead of the original class time being devoted to lectures, the students participated in "a new weekly capstone Team Lab where students work in three-person teams on a problem that is assigned for the Lab" (Foertsch, Moses, Strikwerda, & Litzkow, 2002, p. 270). The eTEACH instructors surveyed students to see how they preferred this new web-based model of lecture to the traditional style. The results were generally favorable, with 78% of students saying, "it was more convenient to watch lectures on eTEACH than to attend live lectures", and only 16% of students "felt [the videos] had a negative effect" (Foertsch, Moses, Strikwerda, & Litzkow, 2002, p. 271). This indicates that using flipped classroom videos might result in better student understanding of the mathematics skills necessary to complete the STEP engineering modules.

Chapter 3: Designing the Module

PROBLEM NEED AND CONSTRAINTS:

The problem need and constraints for my module are not typical of most engineering endeavors. That being said, I still attempted to follow the engineering process the best I could. From the literature review I was aware of the problem of retention of engineering students enrolled in first-year calculus courses at UT Austin and the existence of other modules designed to mitigate the dropout rate.

After talking with several faculty and staff at UT Austin, it was determined that the other modules previously funded by the Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) grant were neither sufficient nor comprehensive in their coverage of calculus material. They suggested that it might be of benefit to STEP, and to UT Austin engineering programs in general, if I was to create a module to fit into the existing framework.

To do this, I mimicked the existing format of the modules. This included a few short video lessons that students would watch prior to attending the module. I was instructed that the videos should be relatively short with some review of content, an introduction as to how the content could be applied to be engineering settings, and finally a preview of what students would be doing within the module itself.

I also had to work within the constraints of the module itself. Historically, the STEP modules have been completed during the recitation sections of the calculus classes. These recitations are led by a teaching assistant (TA) or someone of similar status; very rarely do professors come to recitation sections. As the TA might not necessarily be a content expert with any given topic I chose within calculus, I attempted to make the module somewhat self-contained. Not only should it be relatively student-led in terms of the design task, the module should also be easily adapted to other teaching situations. The recitation sections are about fifty minutes in length, so I wanted to make sure that the module would fit within that timeframe.

MODEL OF THE PROBLEM SYSTEM:

My design project is a teaching module covering a specific calculus topic that students in engineering programs historically have difficulty with. The module is designed to fit within a fifty minute recitation section for Math 408C at UT Austin, but can easily be adapted to other teaching situations, such as a high school AP Calculus class. Students will interact with the module in predetermined ways. Approximately four lesson videos were created, which the students will need to watch prior to interacting with the module. The videos contain background information necessary for fully understanding the purpose and motivation behind the module. They include a recap of the requisite calculus skills, though few computational examples are given. Since the module is designed to be ancillary to the primary instruction, little time is spent on re-deriving formulas and proof.

After a re-introduction of the calculus topic to be explored, the videos present how the topic can be applied conceptually to a real-world situation. The situation might be somewhat contrived, as calculus is not always as directly applicable to the real world as I would like it to be. I introduce any key formulas in the context of the module itself to show

how different parts of the formula have physical significance. Finally, I introduce an engineering design challenge which serves as the core of the module. Students need to use calculus as the central tool to solve a problem, rather than it being the problem itself. The goal is that this will give students a better sense of mastery of this calculus topic since they will be able to better see how it applies in engineering situations.

During the in-class part of the module, students will work in small groups under the guidance of a teaching assistant or professor. The TA will monitor students' progress, give redirection and advice as necessary, and evaluate the final product using a rubric. The module could also function as an in-class project if students are unable to meet outside of class.

SOLUTIONS EVALUATION AND SELECTION:

In order to determine the specific topic that the module should cover, I interviewed groups of people who had experience in taking calculus recently as well as those who have experience in engineering settings. Thus I interviewed two different groups of students and a handful of professional engineers. The first group of students consisted of about thirty high school seniors in an AP Calculus BC class. These students were chosen not only for their proximity to the researcher, but also, at the time that the interview was conducted, for their experience with almost all of the topics covered in any given calculus I and calculus II class. Many of them are planning on studying engineering in college, and some of them might even decide to take the aforementioned classes at UT Austin.

The result of the interview with these students was somewhat revealing. Most of the topics that they found challenging were in the calculus II portion of the class. I listed these on the whiteboard (see Figure 3) as a list of potential topics for the module. The list included advanced integration techniques, applying calculus in polar coordinates (including finding polar area), and sequences and series, including the construction and analysis of Taylor/Maclaurin Series. These topics are somewhat esoteric and almost contrived when compared to the fundamental calculus concepts such as integration and differentiation, which the students studied during the previous semester. It is likely that engineering students at UT Austin and in other programs would agree that these specific topics pose possibly the greatest challenge within the realm of the course, especially considering that the material is taught at a faster pace in college.

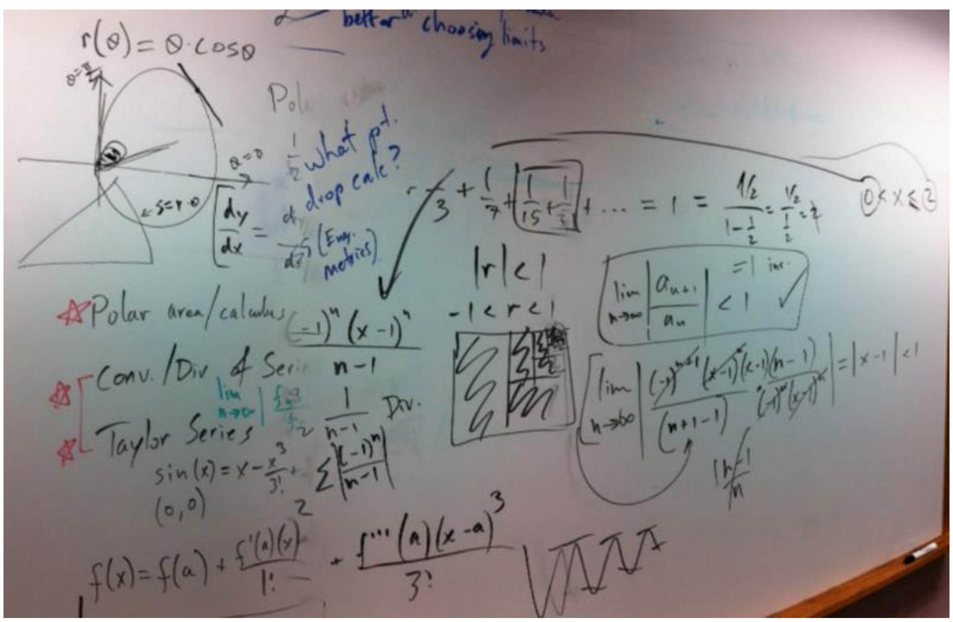

Figure 3: Module Concept Generation

Such is the nature of these specific topics that very few "hands-on" or "real-world" applications use them. I interviewed a handful of professional engineers and also several engineering graduate students to determine to what extent these topics are used outside of calculus. The consensus was actually quite enlightening; not only were these topics in no way used beyond calculus, and perhaps physics, coursework, this sample of engineers and engineering graduate students did not directly use calculus. They admitted that if calculus needed to be evoked to help solve a problem that technology and programming would do it for them. They also reported that only a general understanding of simple calculus concepts such as differentiation and integration was sufficient for the engineering work that they were doing.

While the purpose of this report is not curriculum development or course sequencing, it might be of interest to explore whether these specific topics have a place in engineering education. It seems futile for students to be dropping out of engineering programs because of the challenges they face in a class (calculus II or its equivalent) that is not directly applicable to their field. Since very few, if any, actual engineers use these topics in daily practice, I decided to not pursue a module covering these topics.

Of the remaining topics that both the AP Calculus students and graduate engineering students found challenging was that of solids of revolution. Fortunately, the nature of objects with cylindrical symmetry is quite applicable to real life, since many common objects have this symmetry. Furthermore, the production of many objects relies on processes involving rotation, such as those constructed on a lathe, milling machine, or pottery wheel. I decided that for the module, I would try to incorporate the design and creation of such an object. The students and I brainstormed some possible examples within solids of revolution to incorporate, such as using a wine glass or 3D printer (see Figure 4).

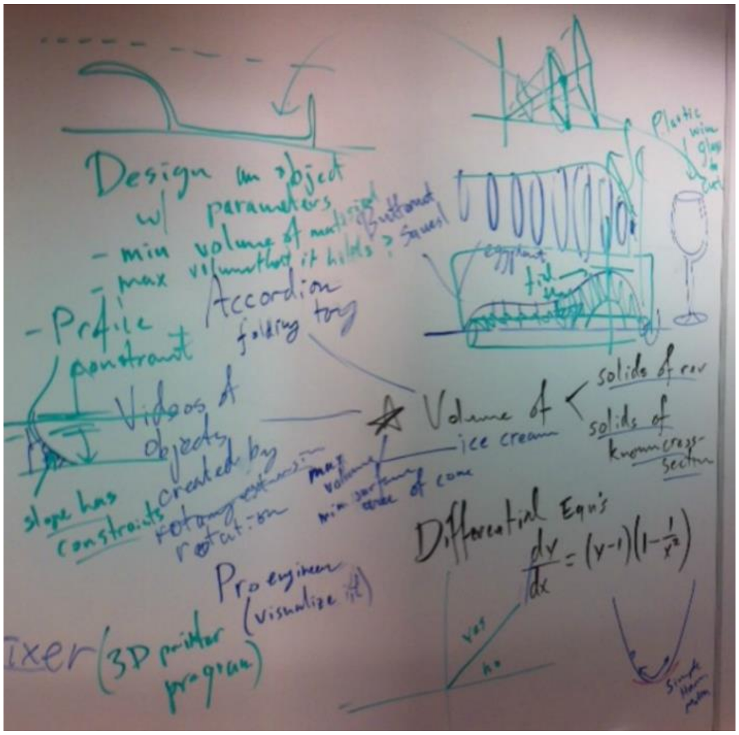

Figure 4: Module Concept Selection

DEVELOPMENT AND PROTOTYPE DESIGN DOCUMENTATION:

Calculus can be applied in several ways to the topic of solids of revolution. At times it helps to think conceptually about rotated solids as just that, a two dimensional profile that has been rotated about an axis to form a three dimensional solid. One can then use integration to analytically determine the volume and surface area of such objects. If an analytical solution is not present, then numerical methods such as Riemann sums can be used to find an approximation for the desired value. My goal is to incorporate some of these core aspects into the module in order to give students a genuine experience without overwhelming them. For the module itself, including the lesson videos, I followed the lesson plan prescribed below in Table 1.

Solids of Revolution Lesson Plan

Established Goals:

The student will learn how calculus is used in calculating different attributes of solids with cylindrical symmetry. Specific attributes include, but are not limited to, cross-sectional area, volume of material, volume able to be contained by the object, and external/internal surface area.

Calculus Learning Objectives:

- Find or approximate the area of a two-dimensional region
- Find or approximate the volume of a solid with known cross sections
- Find the volume of a solid generated when a two-dimensional region is revolved around an axis.
- Qualitatively describe what solid will be formed when a given region is revolved around an axis

Desired Student Understandings:

- Many solids can be described by revolving two-dimensional regions about an axis.
- Mathematical modeling can be used to find the area of the aforementioned cross sections
- Calculus can be used to find the volume of such solids

- Three-dimensional design programs use numerical integration methods to calculate physical attributes of the designed objects. These numerical integration techniques might not give the exact answer, but will be correct within an uncertainty.
- The amount of material used in the fabrication of any object is an important design consideration
- There are different methods of finding volume using integration, and some methods are preferred over others, depending on the geometry of the problem.

Essential Questions:

- How can we visualize solids of revolution with and without physical models?
- What sorts of objects in the real world have rotational symmetry?
- How are these objects designed and manufactured?
- What methods can we use to calculate the volume of material used, surface area, and container volume of such objects?
- What concerns do manufacturers have to consider when these objects are manufactured?

Prerequisite knowledge and skills:

- Find the area of a circle and the area of a washer (difference in areas between two circles)
- Graph elementary functions with and without technology

- Find intersections of two graphs with and without technology
- Given a graph or image, sketch a reflection of it over a given axis
- Identify a "representative slice" to aid in setting up integral calculations

Skills to be learned:

- Identify the axis of revolution on a graph
- Determine appropriate limits of integration based on physical parameters or design restrictions
- Determine whether a horizontally or vertically-oriented integral is appropriate for the problem
- Visualize and describe a solid given its two-dimensional region and axis of revolution
- Identify an appropriate integral formula to use depending upon what attribute of the solid we wish to calculate

Table 1: Solids of revolution lesson plan

VIDEO LESSONS:

A series of videos will be made available to students before they attempt the in-class module. Students will need to watch these videos outside of class and take notes on the videos to demonstrate that they have watched them. Full transcripts of the videos are available in Appendix A.

Video 1: Visualizing Rotated Solids and Qualitative Examples

This video includes an introduction to solids of revolution that focuses on qualitatively describing what happens when a given two-dimensional region is revolved around an axis. I start with demonstrating how basic three-dimensional figures such as cylinders, cones, and spheres can be created via the rotation of a planar shape. An example of this is demonstrated in Figure 5. Then I move on to more challenging figures, namely those that have an inside part that is "cut out" of a larger shape, such as a torus, pipe, funnel, or vase. Again, this video is solely qualitative in its description of these solids. I will check for understanding by asking students questions during/after the video. This will give the instructor a better idea as to how well students understand the visual process of creating a solid of revolution.

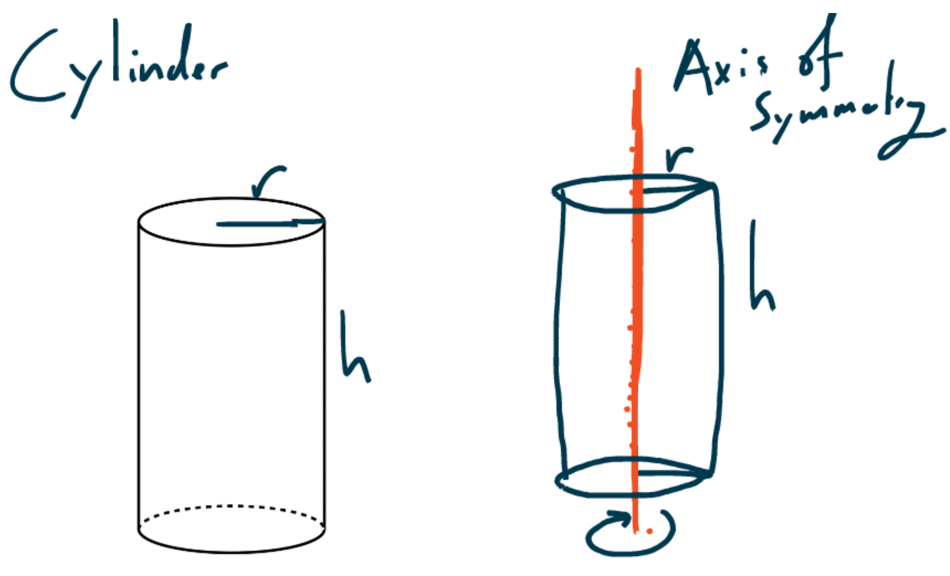

Figure 5: Creation of Cylinder via Rotation

Video 2: Applying Calculus to Rotated Solids

Once students have been exposed to a qualitative view of rotated solids, I now start to explore how calculus can be used as a tool to calculate different attributes of said solids. Though engineering often focuses on just using mathematics as a tool within a larger problem, in this video I introduce and derive certain formulae that the students will use during their module. A non-rigorous explanation is, including applying integration to a squash (see Figure 6), will be provided so that students are able to make some sense of why these formulae look the way they do. The integration process is explained from both a continuous and discrete point of view to explain how numerical integration techniques are used in the absence of integrable functions.

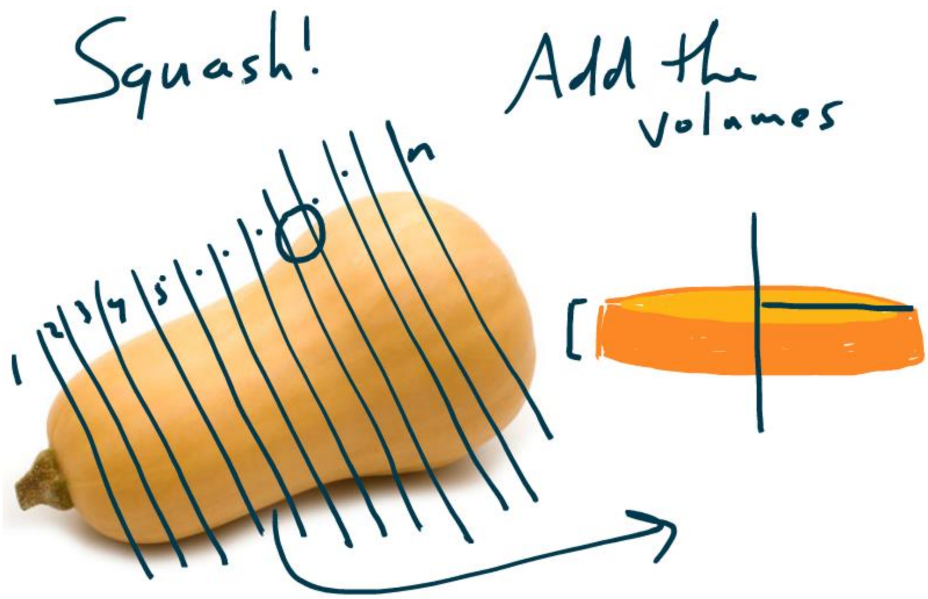

Figure 6: Volume of Disks with Squash

Video 3: Engineering Design Challenge Problem Statement

This video presents the engineering design challenge module that students will complete during the recitation period. It includes the problem statement as well as the constraints that the students must take into consideration. Students will need to design an object with cylindrical symmetry that must have certain attributes. The object must comprise less than a certain amount of volume, be able to hold at least a certain amount of volume, have a base of at least a specified radius, be a specified height, and have a two-dimensional profile of less than a certain area. These constraints are given with the intent that they accurately represent engineering challenges faced in the real world, such as producing objects that will function as designed and are able to be packed efficiently. These specific attributes are detailed more completely in Appendix B: Specifications Sheet.

Video 4: Sample Design Video

The purpose of this final video is to help clarify what I expect of students by the end of the module. In Figure 7, the video presents a design that I do not expect students to copy, but it will give them a good sense as to how to go about designing their object.

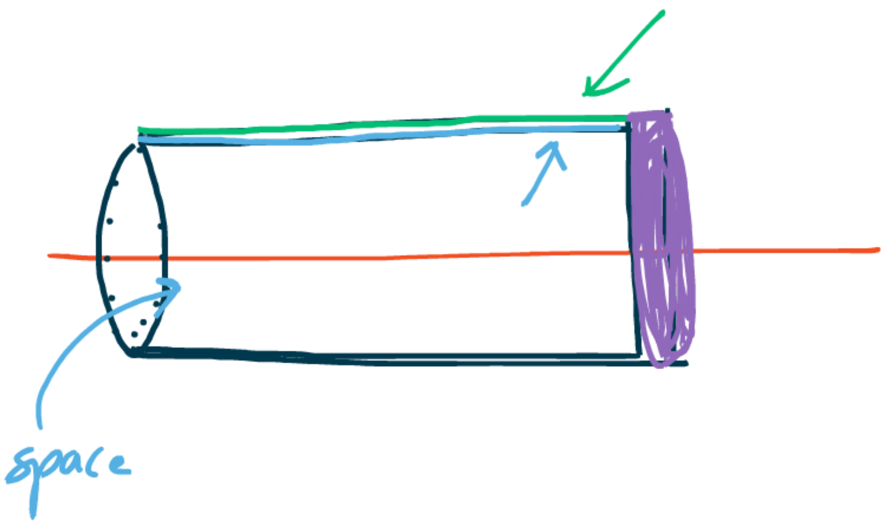

Figure 7: Sample Design in Video

Chapter 4: Evaluation and Feedback

PROTOTYPE TEST DATA WITH EVALUATION:

To develop a sense of the possible effectiveness of the module, I wanted to obtain some critical feedback on it. Due to constraints of time and availability, the best way to accomplish this was to give the module to a small group of engineering education graduate students. This process required going through an Institutional Review Board (IRB) to ensure that the subjects (i.e. engineering graduate students) were not in any risk above that of normal day to day activities. The IRB required a proposal which detailed the actions I was going to undertake and the nature of how the subjects would interact with the module. That proposal is included in appendix D.

This proposal was accepted by the IRB at UT Austin under study number 2015-07-0050 and approved as “Exempt” from needing a full IRB meeting. Before interacting with the module, the subjects were given consent forms which informed them of their role in the project. They were not being tested themselves on their performance on the module; rather they were simply interacting with it with the purpose of giving feedback and comments on it. The informed consent form can be found in Appendix C.

The engineering education graduate students were asked to watch the lesson videos prior to attending the feedback session. Though I did not formally check to make sure that all of them watched the videos, it was clear from the quality of the feedback session that at least a majority of them had indeed watched them. After obtaining consent via the forms, I distributed the engineering design challenge portion of the module and asked the students to discuss it with each other for a brief period of time.

I then obtained feedback from the students by asking specific questions concerning what they thought about the module. The specific questions asked were as follows:

- What aspects of the videos could be improved?
- Was the engineering design challenge too contrived?
- Do you think that this project accurately represents the types of problems engineers use calculus for?
- Discuss how this might compare to an actual engineering project.
- Was the role of calculus significant enough within the module?
- Where might students have issues or need extra guidance with the module?
- To what extent was the module appropriate for first-year calculus students?
- Were any parts of the videos confusing, or could be confusing to first-year calculus students?
- Did the videos make you think about the concept in a new or different way?
- Was there an appropriate use of technology in the module?

I recorded specific comments or suggestions for improvements based on what the students said. I was also able to collect written comments based on what they wrote on the handouts. Revisions to the module will be based on feedback obtained during the feedback session with the engineering education graduate students. I highlight here some of the common and/or important comments that were left as feedback. I group the comments by common theme, where possible.

FEEDBACK CONCERNING THE REAL-WORLD ASPECTS OF THE MODULE:

"Students crave a connectedness from what they are learning in class to what they will experience in the real world. Any opportunity to provide his experience to students is valuable, however, it must be integrated into the course and not merely an afterthought."

"You could consider how design of packaging is done in the real-world. I have a friend who works for Procter and Gamble, and her job is designing cost-effective, visually appealing packaging. The idea of selling chips in a cylindrical can was novel and has made the Pringle what it is. Tying this task to these types of product packaging design engineering may make it less contrived and more real-world."

"Providing motivation before content delivery could make this more effective"

"I think they need 3-D models, not just 3-D like images in a video"

"How to make it more hands-on? Move 2D paper to 3D model? Or start with a 3D object that can be dissected"

"You could begin with a lathe or the manufacturing process first and show how this concept directly ties into engineering before bringing calculus into it."

"I think this is a great application project that might be made even more desirable with the inclusion of a tangible end product (i.e. 3D print or 3D model in CAD/SolidWorks). Maybe have 1 group 'win' the opportunity to have the chance to be 3D modeled so that there wouldn't be the hassle of doing 3D modeling for a ridiculous number of people."

"I think the module could use snippets from CAD or SolidWorks to show how these concepts play out later on during their engineering sequence."

"Consider bringing in tangible objects so that students can reverse-engineer, using mathematics to model the shapes."

"I'm not so convinced that the role of calculus in this module is authentic. It feels contrived (but, that is often unavoidable!)"

It is clear from this feedback that the module needs to be as uncontrived as possible, or at least that the instructor is somewhat up front with how contrived the module is. Just like with any successful lesson, student buy-in is an important factor in improving engagement and motivation. The feedback here makes it clear that making the module as real-world as possible could help to improve student learning outcomes.

Based on this feedback, I can incorporate some significant content revisions into this module. The videos themselves could include better graphics to more accurately depict three dimensional objects and their cross-sections. Since the students will at some point take classes involving the use of CAD/SolidWorks, it would be a further reinforcement to show how these programs can be used to create and design solids with cylindrical symmetry.

I might also consider restructuring the order of the videos to start with an actual real-world example, such as the Pringles can or lathe, so that students immediately see the end result of this aspect of the engineering design process. Time and resources permitting, I could even try to find an engineering process involving calculus to be used as a demonstration to students so that they can immediately see the benefits of calculus before attempting it themselves. Treating the module as a reverse-engineering project might also have success, since analyzing an object with cylindrical symmetry might be more revealing and insightful than attempting to create one's own object.

The use of 3D printers was mentioned several times as a way to help students get "hands-on" experience with the module. Unfortunately, most 3D printers do not use rotation to create objects, instead preferring rectangular methods such as deposition. Furthermore, the availability of 3D printers and the limited time in which the module must be completed means that 3D printers could not realistically be part of the module process. The comment that a group could be declared as having a "winning design" might be valuable, since during class the object could be used as an example for the rest of the students. This might also have the effect of encouraging more students to attend and be more engaged with the module.

FEEDBACK CONCERNING THE LEVEL OF RIGOR AND THE ROLE OF CALCULUS

"The actual calculus seems like it needs to be more rigorous (analytically). Require non-linear components?"

"A common reply that students give to more contrived experiences such as this is that, as engineers, they will have technology (computers) to calculate these types of things. Perhaps a discussion of why an understanding of calculus is important here. Can engineers rely solely on computers? If so, why is the calculus important at all? If you can dispel these feelings that the computer will ultimately do everything for them, I believe it will feel less contrived."

"Cheat sheet with functions—could help with time constraint"

"Have students plan their design on a calculator and use the technology to develop regression equations for their designs"

"Printed overview for TA in case students don't watch videos"

"Consider scaffold the learning experience by anticipating areas in which students may need extra guidance during the in-class module. Considerations may be made for foundational skills such as writing linear equations and scaling the engineering paper itself."

From this feedback it is clear that the engineering design challenge was not as detailed or specific as it could have been in establishing expectations for student work. The example in Video 4 and the written example that I showed to the engineering education graduate students consisted of all linear components. I would expect that a college level calculus class would incorporate more rigorous functions. However, since the plotting and translating of functions onto a coordinate grid is not the primary focus of the module, I would allow students to use technology such as regression equations to accurately write equations representing the different parts of their design. To increase the rigor of the module, I could limit the number of sections described by linear functions and/or require that students use a prescribed variety of functions. Engineers often use mathematics as a tool in a project, rather than the focus, so to reinforce this notion I might also provide students with a "cheat sheet" of functions that they could choose from. It would still be their responsibility to plan their object and determine how the functions fit into the integration formulas.

As it is currently written, the module is too open-ended and does not contain enough rigor to satisfy learning objectives at a college level. It seems too contrived, so to mitigate this I will attempt to further scaffold the module by incorporating specific tools to improve the student experience. The teaching assistant (TA) will also be given a document outlining the module and also specific prompts to ask students who seem stuck or need redirection on their project designs. Many of these changes to the module would reinforce the notion that mathematics is a tool that engineers need, but without sacrificing the central role that the calculus of solids of revolution plays in the design of these objects.

FEEDBACK CONCERNING THE VIDEOS

"Maybe a design challenge type video so they are exposed to it in order to fit activity into 50 min"

"Could students help film certain physical aspects of solids of revolution to supplement videos (instead of relying on drawings alone?) [This would mean the project becomes iterative]"

"The video was personally a good review for me—I haven't done calculus-level math in a very long time. It was thorough without being dry or overwhelming. The platform was nice as well, very user friendly. I also really liked video 4 that gave an example. When students come to class/recitation they can immediately start working."

It seems that feedback on the videos for the module was generally positive and supportive. I made a conscious decision to not make a video outlining the specific engineering design challenge. This was because it is significantly easier to make and edit a document containing the parameters of the challenge, rather than making and remaking a video with the specifications. The vague language contained within Video 3 was also used on purpose so that this module could be adapted in different calculus contexts. It gives the instructor or TA some freedom in determining what aspects of the project to highlight.

I did not take into consideration the relative ease of student video creation. With the prevalence of smartphones with video recording capabilities, I could require as part of the pre-module assignment that students find and document (in video format) a given number of objects with cylindrical symmetry to demonstrate their understanding of the content discussed in the video. This could then form the basis for their engineering design challenge, which could be altered to incorporate the reverse-engineering and/or redesign of an object that they chose.

FEEDBACK CONCERNING THE ROLE OF ASSESSMENT OF STUDENT WORK

"I agree that it should be graded somehow. A rubric would be good to have. It's definitely a meaningful, worthwhile activity but for the amount of effort they put in, it needs to be tied to their grade/future assessments in the course to ensure that they take it seriously and produce work that is quality, college level work"

"Perhaps including a short answer assessment question on the next unit test"

"Include other aspects of the module within the class"

"Fear of low engagement/attendance with the module if there is no grade attached to it"

"The way in which modules are introduced, executed and graded and of utmost importance to the success of the module. The module should not be an afterthought or a peripheral component to the course."

This was one area of feedback that I did not anticipate. Often one forgets the role of student interest, motivation, and buy-in when planning lessons such as this module. In my initial plan, I did not incorporate any vehicle for student assessment or feedback on the module. I also assumed that attendance at the module was compulsory, whereas in reality many UT Austin students choose not to attend recitation if they knew it was a module day. While intrinsically motivating students is preferred above extrinsically motivating them, one could increase attendance and participation in the module by offering or requiring the assessment of student work.

The module itself need not be explicitly graded; instead, the professor running the class and overseeing the module could then work to incorporate a short answer question on the next exam to allow students time to reflect and process their work within the module. With more planning and coordination within the class itself, different parts of the module could be incorporated into either the mathematics class itself or any corequisite engineering classes, such as a demonstration of a lathe or milling machine. Furthermore, the module could even become sort of a capstone project within the class itself, rather than an ancillary exercise. Certainly it would need to be developed more and have more student interaction, but by becoming a sort of unit project, more time could be spent on the various subtopics already mentioned within the module. As was mentioned, the relationship between the modules and the course itself is paramount to the success of the module. Without the class, the module is almost nothing, and without the module, the class will carry on. Thus the overall goal of the module should be a nearly necessary enrichment experience, one that cannot be easily replicated in class.

The engineering education graduate students clearly indicated that if there was no grade or feedback mechanism for students, there would likely be low engagement and participation with the module. In my revisions to the module, I will work to include a grading mechanism such as a rubric so that students are able to see what aspects of the module are deemed important with regards to the engineering design process.

Documentation of Final Module Design & Suggestions for Future Work

Based on the feedback I received from the session with the engineering education graduate students, I have some specific recommendations to improve the module. The first is that, regardless of how well the module is designed, it is at its core contrived as it was developed specifically to incorporate a calculus topic. Being up front with students about this might actually increase their participation and engagement with the module. As engineering students, they should know that professional engineers rarely use calculus and, in the event that calculus is required, there will probably be technology available to do any computational work. That being said, it is important that they understand the concepts and how design choices affect the end product from a computational standpoint. No engineer relies solely on computer results. A competent engineer will verify computer results with hand calculations to provide a sanity check. Thus, an understanding of the calculations, even when done by computer, is required.

Another recommendation to consider is to revamp the entire module to make it a reverse engineering project. Students could start with a premade container or object with cylindrical symmetry and then use calculus to deconstruct it. One of the engineering education students recommended looking into tissue paper party globes. These have the unique design of starting as a two dimensional cross section and then literally rotate around an axis to form a three dimensional objects (see Figures 8 and 9). I could take some of these party globes and then have students map their designs from a grid to the globe so that they could then visualize their object iteratively. It is relatively simple to fold these back up, make alterations, and then check the new construction.

Figure 8: Two-dimensional solid of revolution (profile view)

Figure 9: Three-dimensional solid of revolution (axis view)

With regard to flow of the module, a handout could be made for the teaching assistant to follow in the case that students were not making sufficient progress. I would couple this with a rubric so that students could also know what the important learning outcomes were. This way they could focus on those and not necessarily on artistic details. In order to encourage using more challenging functions, a quick reference guide of functions could be provided that could be easily adapted to their design. The TA would be informed on how to use this as well, so that he/she could easily help students adapt these functions to their designs. I have included a sample TA guiding document as well as a sample rubric and equations inventory in Appendix E.

Chapter 5: Applications to Practice

DEVELOPING ENGINEERING AWARENESS

I am continuously grateful for the Master of Arts in STEM Education-Engineering program and the National Science Foundation grant that funded it (Allen, n.d.) (http://www.nsf.gov/awardsearch/showAward?AWD_ID=0831811). Prior to enrolling in the program and taking these classes, I had little to no experience with engineering or the engineering design process. I did not really understand what engineers did or how they used mathematics and science to solve problems. It was enlightening to experience firsthand the engineering design process specifically with the focus of adapting it to secondary classrooms. I feel much more qualified to represent engineering careers and practices to my future students. This is due to the quality of the in-class projects my classmates and I completed as well as the research and readings into the theory of STEM education we discussed in our classes.

Because we completed a variety of accessible and manageable projects in class, I feel well prepared to incorporate new elements into my AP Calculus classes to highlight how what my students are learning can be used in solving real-world problems. Indeed, I intend to use a modified version of the module discussed in this report in my class as either a unit project or supplemental exercise during the time after the AP exam.

DEVELOPING ENGINEERING HABITS OF MIND

Before completing this master's degree, I approached most problems with a combination of the scientific method and mathematical reasoning. I would observe patterns, make predictions about a certain behavior, develop a method to test those predictions, and then construct some sort of argument or proof to justify my responses. This worked fairly well for most scenarios for which I used it. However, during our first engineering project, I found it incredibly difficult and frustrating to approach the problem from a scientific and mathematical perspective. The project was to design a fuel efficient vehicle that would be able to both go fast and have a large volume. There were too many variables to keep track of, modify, and determine how they affected the final result. By learning and applying the engineering design process, I was able to more clearly see how one can make changes to an existing design and still be able to quantitatively and qualitatively describe any improvements or deficits. I learned that a core idea of the engineering design process was to improve upon designs that had already been created for a certain purpose. During the vehicle challenge, my team started with a relatively novel design, but then went through several iterations of improving that design.

When we tested our design against those of other groups, we quickly found that it was markedly different. This was despite going through several iterations of improvements. It seemed that other groups had started with prioritizing different aspects of the design parameters and thus had very different final products. When we compared the performance of the many different models, it was insightful to see to what extent the different designs successfully satisfied the parameters of the challenge. Our group decided to prioritize the volume of the vehicle over its speed, whereas other groups had decided to do the reverse. In the end, we were more concerned about the varying successes of each group rather than the "winner" of the challenge. I found this a valuable aspect of the engineering design process, that at the end of the process, everyone benefits not only by going through the process themselves, but also by observing and reflecting how other groups interpreted and approached the same problem.

With my newfound understanding of the engineering design process, I will now be implementing the engineering design process in my classroom. While the process might not be the best for teaching and understanding specific skills, it can be used as a final project so students can see how multiple topics and concepts can be tied together to solve problems. In fact this is the motivation for the module described in this report and what will hopefully be several more activities and projects that I can incorporate into my own classroom.

DEVELOPING AN UNDERSTANDING OF THE DESIGN PROCESS AND TEACHING

For my report, I decided to contribute to the STEP project by developing a hands-on calculus module. In order to do this, I had to decide what topic my module should cover. What better way to decide this than to use the engineering design process! I started with a customer needs analysis and interviewed pre-engineering students in calculus, graduate engineering students, and a few professional engineers about what topics in calculus presented the most difficulty in learning. Of these topics, I asked them which topics were the most and least useful in practical everyday engineering. Based on these lists, I chose a topic, solids of revolution, that was both challenging and practical in a variety of engineering settings.

The report itself focuses on both the process for choosing this topic for the module, the creation and development of the module, and then the feedback the module received after being given to a group of engineering education graduate students. While the module was not able to be tested on pre-engineering students, I am confident that the feedback these students gave will be useful in modifying the module so that it can be effective with a younger, less experienced audience.

Based on the (hopeful) success that this module has, I feel that I sufficiently understand the purpose of the engineering design process as well as knowing under what circumstances it is appropriate to implement. Furthermore, the process I followed with designing this lesson/module could easily be extended to other lesson plans.

For example, after designing and implementing a lesson, I would need to test its efficacy. I would do this through a variety of means such as test data, formative assessment, and feedback from students. Armed with all of my data, both quantitative and qualitative, I would, time permitting, draw up some rudimentary conclusions about how the lesson went and why. Whether or not these conclusions were valuable, the time for altering the lesson while it was being taught had already passed.

After completing the UTeach*Engineering* master’s program, I have a new mindset—the engineering design process—which I can use to both design and implement my lessons as well as teach as a topic itself. By combining the engineering design process with a teaching mindset such as understanding by design, I can guide my classes in a constant implementation and redesign of my lessons (Wiggins & McTighe, 1998, p. 6). This would be done with main result being significantly reduced turnaround on improvements to the lessons. By including students in the design of lessons process, students will also learn to take on more ownership of their learning.

Appendix A

Appendix A contains the transcripts of the four videos created for this module. They are not exactly word for word what is said in the videos, but they capture the essence and content of each video. A URL is also provided for each video.

VIDEO 1: VISUALIZATION OF ROTATED SOLIDS AND QUALITATIVE EXAMPLES

Available at: https://www.educreations.com/lesson/view/calculus-module-part-i-visualization-and-qualitati/32564697/

We interact with the three dimensional world almost every moment of our waking lives. We can observe, hold, and imagine 3D objects with ease since they form the majority of our experiences. Of the objects designed and made by humankind, many have cylindrical symmetry to them. Bottles, cans, canisters, pens, bowls, pistons, lids, cups, and buckets are just a few of the many objects that are cylindrically symmetric. In this video, we will explain what it means for an object to have cylindrical symmetry, and then discuss how nearly all objects with this symmetry can be visualized by the rotation of a figure in a two-dimensional plane. Let's get started.

Probably the most basic object with cylindrical symmetry is just that, a solid cylinder. A cylinder is most often though of three-dimensionally as a circle that has been "popped out" into space, thus giving it a height. However, we can also imagine forming a cylinder in a different way, namely through rotation. Instead of starting with a circle, we will start with a rectangle with the same dimensions as the radius and height of the cylinder. We will then choose a side of the rectangle parallel to the height and rotate the entire shape around this. Imagine taping a rectangular sheet of paper to a wooden dowel on one side, and then rotating the dowel. The shape that is traced out in three dimensions is a cylinder.

Let's explore some other common shapes that can be described with cylindrical symmetry. To be clear, an object has cylindrical symmetry if it can be created by rotating a two dimensional shape around an axis. A sphere has cylindrical symmetry because we can rotate a semicircle about its flat edge. On the other hand, a cube or prism does not have cylindrical symmetry because no object could be rotated to form it.

When we start with a different shape then a rectangle, say a triangle, we will end up with a different three-dimensional object. When we take a triangle and rotate it around one of its edges, what shape do we get? We can trace out the path of the other corner of the triangle and see what we will get a three dimensional cone. Pretty cool! If we rotate the original two dimensional shape instead around its shorter leg, we also get a cone, but this one has different dimensions from that of the first.

There are other, more complicated shapes that can be described with cylindrical symmetry. What happens if we take a rectangle but instead of rotating it around its edge, rotate it about an axis a little bit off the edge? Even though it doesn't appear that this will form a solid object, it does indeed! The space in between the two-dimensional shape and the axis of revolution stays as an open space inside a solid object. In this case, we can either get a tube or a washer, depending on the dimensions of the original rectangle and about which side—long or short—it is rotated.

If we take a more esoteric object, such as a vase or wine glass, we can reverse the process to determine what the original two-dimensional outline would have looked like. In the case such an object, we can imagine cutting it in half along its axis of revolution, essentially revealing the cross section we need. Half of this cross section, when rotated about its axis, would yield the original solid.

Part of your engineering challenge will be to design an object with cylindrical symmetry. It is important that you be able to transition between a two dimensional representation of a three dimensional object and vice versa, especially without the aid of technology. Some objects are even constructed or manufactured using processes involving cylindrical symmetry, such as a lathe or pottery wheel. Thus knowing how to visualize such objects in your head can result in more efficient manufacturing and design.

VIDEO 2: APPLYING CALCULUS TO ROTATED SOLIDS

Available at: https://www.educreations.com/lesson/view/calculus-module-part-ii-calculating-attributes-usi/32564802/

Now that we have some proficiency at imagining and visualizing solids of revolution, we can now explore how the calculus concept of integration can be applied to calculate different attributes of a solid. These attributes include volume, cross-sectional area, and surface area. Let's first review how the integration works at a conceptual level. Let's imagine that we want to make a nice side dish for dinner. Butternut squash sounds good. As I prepare the butternut squash, I get bored (but not inattentive with my sharp knife!) and start thinking mathematically about the squash. How would I calculate its volume? I notice that as I slice the squash, I get cross-sections that are nearly perfect disks. I know how to calculate the volume of a disk since it is essentially a short cylinder. So to get the entire volume of my squash, I would cut it up into disk-like sections, find the volume of each one, and then add up all of those volumes. If I wanted to get a better approximation, then I could make the disks thinner as to reduce any error caused by assuming that the sides were perpendicular to the cut edge (when in fact they're not). In fact, if I wanted to find the volume *perfectly*, I could make each cut impossibly thin, resulting in infinitely many slices, but the error in the volume calculation would be reduced to zero. This is the concept of integration, from which we will use to develop a more explicit formula.

Let's apply this now to a two dimensional region that can be described by an analytic function f(x). In this figure, we have a generic function that will be revolved around an arbitrary axis. We will now apply the method of integration by disks. Each disc has volume given by pi r squared h, where the radius is the length from the function to the axis of integration ($f(x) - a$). The height h is Δx, which becomes dx when we transition to the integral notation. We will then integrate from one end of the figure to the other, giving us the disk method of integration formula. Notice that conceptually that the volume is essentially described as the sum (integral symbol) of circles (πr^2). As the function changes value, the size of the radius (and thus each cross-section) changes as well; however, the power of integration takes care of that for us, leaving us with a nice way to calculate the volume. Note that we will leave the actual calculation of such an integral as an exercise for technology.

As mentioned in the first video, some three dimensional cylindrically symmetric objects have an "empty space" contained within them. In order to calculate the volume of these objects, we can imagine that after rotating the outermost function and calculating the volume of this large object, we can then integrate the inside function to obtain the volume of the inner space and then subtract the two. This has the end result of a subtraction of integrals: outer integral minus inner integral, or:

$$\int \pi r_{outer}^2 dx - \int \pi r_{inner}^2 dx.$$

This formula is known in calculus as integration by washers. While these formulas are standard in most calculus textbooks, we feel that learning them from an object-oriented perspective can help us understand how they are applied in engineering settings.

Not all objects, however, are described by "nice" (or at least, integrable) functions. In the case of most engineering design tools, such as CAD software, numeric integration methods are used. This essentially means that instead of finding the actual antiderivative of a volume integral and then using the fundamental theorem of calculus to evaluate it, the technology will instead perform a process similar to what we did to the butternut squash. Though the program doesn't show the process, it will slice the object into thin disks, calculate the volume of each one, and then simply sum these numbers. It ends up being faster (computationally-speaking) to do this than analytically integrating the functions.

VIDEO 3: ENGINEERING DESIGN CHALLENGE

Available at: https://www.educreations.com/lesson/view/calculus-module-part-iii-engineering-design-challe/32566357/

In this video, you will learn about your engineering design challenge, for which you will apply what you've learned about solids of revolution. For your design challenge, you must design a vessel for ACME Liquid Assets, Inc. The company wishes to pack and ship vessels, in which will be packaged and served ACME's newest concoction: Integratorade (an integral part of any balanced life. Integratorade: just du it!). You have the choice of designing either the container in which the beverage will be shipped, or the container in which it will be served. Each of these vessels requires several engineering decisions to be made. They must meet a set of criteria, which will be provided to you, but will definitely include the fact that both vessels must have cylindrical symmetry.

Also, as a marketing move, ACME has decided that traditional shipping/serving designs should be avoided; Integratorade should be package in its own unique container, and certainly be served in a one-of-a-kind vessel! Any designs too closely resembling traditional (boring!) products will be rejected. Your design needs to be represented by any number of integrable functions; you may use technology to help plan your design and evaluate any integrals.

VIDEO 4: EXAMPLE ENGINEERING DESIGN

Available at: https://www.educreations.com/lesson/view/calculus-module-example-design/32566411/

In this video we will be looking at a sample design for the calculus module on solids of revolution. Recall that ACME Liquid Assets, Inc. has commissioned you to design a container for either shipping or serving their beverage in. They want you to design it using a number of specifications and design features that were outlined in the previous video. However in this video I want to go through what a possible design using cylindrical symmetry looks like. The first thing you will need is an axis of rotation. Everything will be based around this. Because we are using functions, it might be more useful to draw this axis horizontally, akin to the x-axis.

Now this is a design specifically of what not to do. For example, if we wanted a very boring design, we could simply draw the following design. Notice that when we rotate this around the axis we would get a very basic glass-shaped object with right angles and rectangular profile.

What you will need to think about, however, are the functions you will need to use to create the different parts your design before you substitute them into integral formulas. Essentially the design challenge will be to design a similar object and then use integral calculus to describe and compute the volume of certain aspects of your design, which will be detailed on a handout you will receive during the in-class module.

Appendix B

Appendix B contains the Specifications Sheet that students will receive when they start the module. We have tried to design the specifications sheet so that it can be easily altered based on the needs of the instructor or teaching assistant.

SPECIFICATIONS SHEET

Shipping Container:

- Must be less than 30 cm tall and fit within 10cm x 10cm square (to fit in ACME's shipping boxes)
- Base must be between 9.5 and 10 cm in diameter to ensure stability during transit and storage
- Must have an opening at the top
- Maximum top diameter (of opening) ~ 3 cm
- Must hold at least 400 mL (cm^3) of Integratorade
- Volume of material used for the container itself must be at least 100 mL but less than 350 mL
- Minimum thickness of container ~ 0.3 cm

Serving Container:

- Must be less than 30 cm tall and fit within 10cm x 10cm square (to fit in ACME's shipping boxes)

- Base must be between 9.5 and 10 cm in diameter to ensure stability during transit and storage
- Must have an opening at the top
- Minimum top diameter (of opening) ~ 6 cm
- Must hold at least 300 mL (cm^3) of Integratorade
- Volume of material used for the container itself must be at least 80 mL but less than 450 mL
- Minimum thickness of container ~ 0.2 cm

Your design proposal needs to include the following calculations to demonstrate that you meet the design criteria:

- Integrals representing the volume of the material used for the container
- Integrals representing the volume of Integratorade that fits into your container
- Document any design choices that you made as well as how your design evolved over time
- On graph paper, sketch the two-dimensional outline of your design, including labeling the functions you chose
- Write a short reflection as to the nature of your design. What motivated you to choose the design you did, and how did the role of calculus help shape your decisions?

Appendix C

INFORMED CONSENT FOR STUDENT CLASS PROJECTS

Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) at the University of Texas at Austin: Calculus Module on Solids of Revolution

Name: Mathew Deram

Department: Science, Technology, Engineering, and Mathematics

Email: mathew.deram@gmail.com

Phone: (847) 525-3921

The University of Texas at Austin

Faculty Sponsor: Dr. Richard Crawford; ETC II 5.160, (512) 471-3030, rhc@mail.utexas.edu

You are being asked to take part in a study for a student class project. The purpose of this project is to learn more about the appropriateness of a calculus module for first-year engineering students. If you choose to take part, we will ask you to watch lecture videos, interact with a module centered on an engineering calculus topic, and submit feedback in either survey (written) or oral (interview) form. We expect that it will take about 30-60 minutes for the videos and an additional 30-60 minutes to interact with the module and give feedback. You can contact the faculty member at the above address and phone number to discuss the project.

The risks of participating in this project are no greater than everyday life. There are no costs for participating. You will not directly benefit from participating. The information you provide today will not be shared outside of the classroom during this semester. Your responses will be recorded neither with video nor with audio equipment; responses may be recorded in written form. Your real name will not be recorded or used in the class report.

Your participation in this project is voluntary. You may decide not to participate, choose not to answer any question, or stop participating at any time **without any penalty**. If you want to withdraw from the project, simply stop participating. If you have any questions, contact the faculty member listed above. Your decision whether or not to participate will have no affect with your relationship with the University of Texas at Austin.

If you have any questions about the study, please call Dr. Richard Crawford at (512) 471-3030 or send an email to rhc@mail.utexas.edu.

If you are willing to participate, please indicate by signing below.

Signature of Subject **Date**

Appendix D

RESEARCH PROPOSAL

1. Title

Science, Technology, Engineering, and Mathematics Talent Expansion Program (STEP) at the University of Texas at Austin: Calculus Module on Solids of Revolution

2. Principal Investigator

Dr. Richard Crawford, rhc, Mechanical Engineering

Co-Investigator: Mathew Deram, mrd2274, UTeach Engineering

3. Purpose

The main focus of this project will be to develop and test an engineering module within the context of a first-year calculus class for engineering students. We will target mathematics that are traditionally challenging for calculus I and calculus II students, such as calculating the volume of solids of revolution. The module will serve two purposes. First, students will see how math fits into the engineering design process as a tool, and second, students will better understand the specific math skills better. Before the students do the module, we will pre-teach the requisite mathematical skills so that the math itself is not new. Since few of the target students have taken formal engineering classes, they will also learn about the engineering design process. The research I will collect is an evaluation of the module and will include feedback from STEM graduate students and professors. It will not include these participants' performance on the module; rather, it will include their opinions on the appropriateness and predicted effectiveness of such a module on first-year engineering students.

4. Procedures

Participants in this study will be administered and interact with a module designed to introduce first-year calculus students to a hands-on engineering activity. Participants will first watch lesson videos prior to the face-to-face session. During the session, participants will discuss the content discussed in the video and apply it to an engineering design project. After the completion of the module, participants will be given a survey and have the opportunity to critique and offer feedback on the module itself. Questions on the survey will be aimed at determining how appropriate the module is for first-year calculus students enrolled in engineering programs and how the module could be improved. Participants will not be evaluated on their own personal performance on the module and its learning objectives. The module will not advertise any benefits for participants, and there are no risks greater than those of everyday life.

a. Location:

Data collection will happen at the University of Texas at Austin campus in the Sanchez Building, Room 316.

b. Resources:

No external funds will be needed.

c. Study Timeline:

From data collection to dissemination of results should take less than 1 month.

5. Measures

The study measures will include paper surveys with questions designed specifically for this project as well as an open-ended group interview process during which participants can voluntarily discuss the merits of the module and/or suggestions for improvement. Participants will be involved in the feedback session for approximately 30-60 minutes.

6. Participants

a. Target Population:

Approximately 20-30 graduate students, ages 22-60

b. Inclusion/Exclusion:

No exclusion criteria.

c. Benefits:

No direct intrinsic value will benefit participants other than the knowledge that the developed module could be more successful at teaching calculus to first-year engineering students.

d. Risks:

The potential risk to the participants is no greater than that of everyday life.

e. Recruitment:

Participants will be recruited through direct soliciting in a STEM education class. Student participation will be voluntary and confidentiality will be maintained throughout and after the survey.

f. Obtaining Informed Consent

I am applying for a waiver of signed consent because participants will be subjected to no more than minimal risk. Furthermore, I am asking them survey questions that under normal circumstances wouldn't need consent to be answered. No identifier information will be collected, and the survey data collected will be held securely after they are collected. Information for consent will be provided via a verbal explanation of what they will be doing and the types of questions they will be answering. Participants have the option to not answer any or all questions that they might find invasive. Considering all of the questions will be specifically tailored to the nature of the educational calculus module, it is unlikely that any of the participants will have moral, ethical, or personal issues with any of the questions.

7. Privacy and Confidentiality

I will protect privacy of participants by giving participants the option to not answer certain questions if they feel that their privacy is at risk of being compromised. Collected surveys will also contain no identification information linking participants to their responses. Any face-to-face interactions will also remain anonymous.

Confidentiality of the Data or Samples:

a. Data will be collected via paper survey.

b. Data will not need to be securely stored since it will not contain any identification information and will not endanger the privacy of any of the participants.

c. Data will be kept at least a month, perhaps longer until it is deemed no longer needed or relevant, but no longer than 1 year.

d. Data will be kept anonymous: Data will be kept until it has been determined it is no longer needed or relevant, at which point it will be securely destroyed.

e. Compensation: Participants will not receive any compensation.

Appendix E

Appendix E contains a document designed to help the teaching assistant with administering the module, a sample rubric for the assessment of student work, and an inventory sheet of equations that students can use in modeling their designs.

HANDOUT FOR TEACHING ASSISTANT:

Welcome to the Calculus Module on Solids of Revolution

We will assume that you are familiar with the videos on this module and the engineering design challenge; refer to those resources if you have specific questions concerning them. The purpose of this document is to help you, the instructional assistant, guide students through the module.

You should first ascertain which students did not watch the pre-module videos and provide the following demonstration as a recap of the video. Take a pre-cut party globe in the shape of a cylinder and lead students through a brief discussion about how we can think of objects with cylindrical symmetry. Highlight some of the talking points from the video, such as the notion that objects with cylindrical symmetry can be reduced to a two-dimensional cross section. Ask them to predict the cross sections required to produce a sphere, a cone, and a glass. Demonstrate these with pre-cut party globes or simple images, such as those shown in Figure 10. The main idea here is that they understand how two-dimensional planar objects can be rotated to form three-dimensional solids.

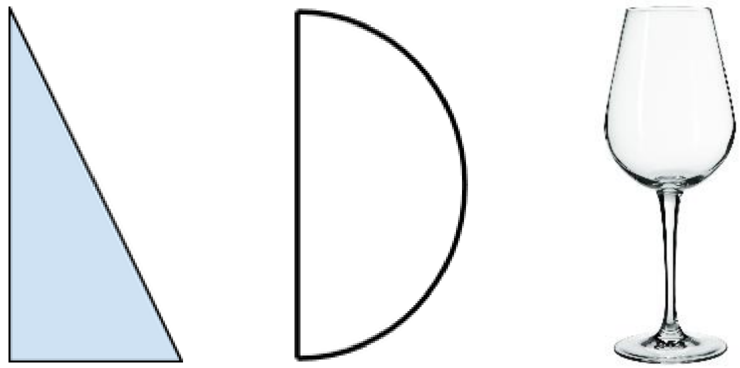

Figure 10: Sample shapes to revolve

If not all students understand the design challenge, show them a premade design (see Figure 11). Make it clear that their design needs to be more complicated than this and use more nonlinear sections, but the concept of breaking up the design into segments is definitely encouraged. They can even plot their design on graph paper and then use a technology tool such as a TI calculator or spreadsheet software to find the equations using regressions. You should make sure to be familiar with how to do this on both a calculator and on spreadsheet software such Excel or Google Sheets (see Table 2). Using regressions will help students focus on the calculus of the module because they will spend less time actually determining the equations of the functions they wish to use.

TI Calculator	Excel/Google Sheets
Stat, Edit, enter points in L1, L2 Stat, Calc, <choose appropriate regression>	Enter points in Column A, Column B Excel: Insert Chart, Right click data, Add Trendline Google Sheets: Insert Chart, Customize, Trendline

Table 2: Calculator and Excel Regression Instructions

For a 50-minute module session, students should spend about:

- 15-20 minutes on an initial design (determining functions via choosing them from the list or using regressions)
- 15-20 minutes on substituting these functions into the integration formulas to compute the volumes for the module and iteratively altering the design based on these data.
- 10-15 minutes on writing up the module reflection

A sample design with integral work is shown in Figure 11 as reference.

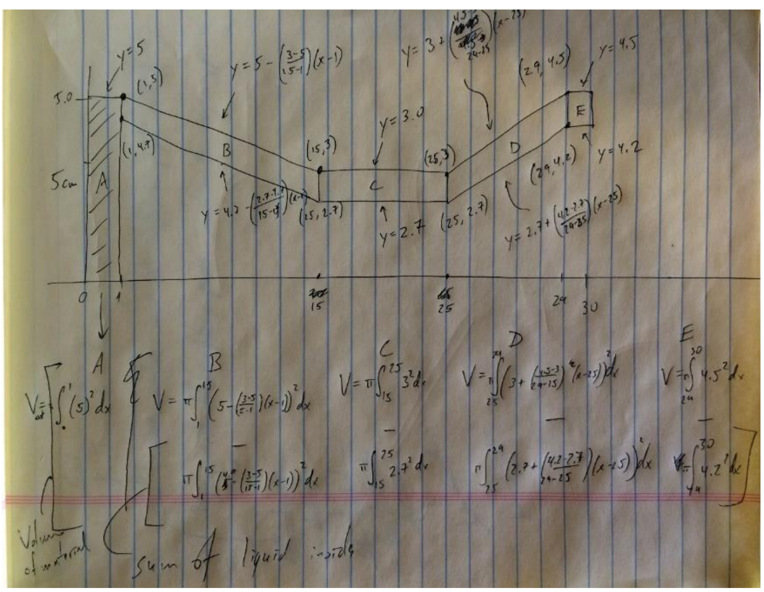

Figure 11: Sample Design with Labeled Work

To assist in teaching the module and assessing student work, a grading rubric is given in Table 2 and sample functions sheets are given in Figures 12-15.

Grading Rubric for Module on Solids of Revolution

Criterion	3	2	0	Total
Functions	Uses a wide variety of functions	Uses some variety of functions	Uses little/no variety of functions (e.g. all linear)	
Integrals (volume of material used)	All integrals present and well-documented	Some integrals present, or documentation incomplete	No integrals or documentation	
Integrals (volume of liquid contained)	All integrals present and well-documented	Some integrals present, or documentation incomplete	No integrals or documentation	
Documentation of Design	Documentation of design with reasoning	Documentation of design with little reasoning	No documentation or reasoning	
Sketch/Outline	Clear, well-labeled outline	Somewhat labeled outline	No/incomplete outline	
Reflection	Insightful, demonstrates connection between calculus and design challenge	Some insight, demonstrates some understanding of calculus within module	Little to no insight, incomplete understanding	

Table 3: Sample Rubric for Assessing Module

SAMPLE FUNCTIONS SHEET

Linear $y = y_1 + m(x - x_1)$

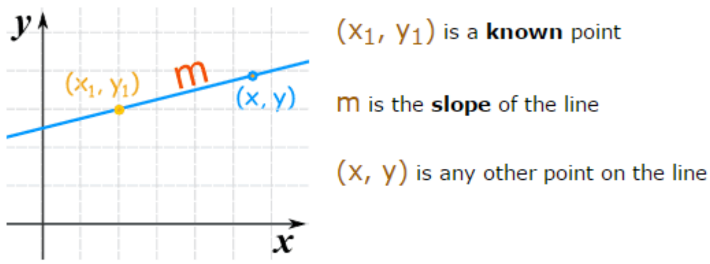

Figure 12: Linear Graph ("Point-slope Equation of a Line," n.d)

Quadratic $y = k + a(x - h)^2$ and **Square root** $y = k + ax - h$

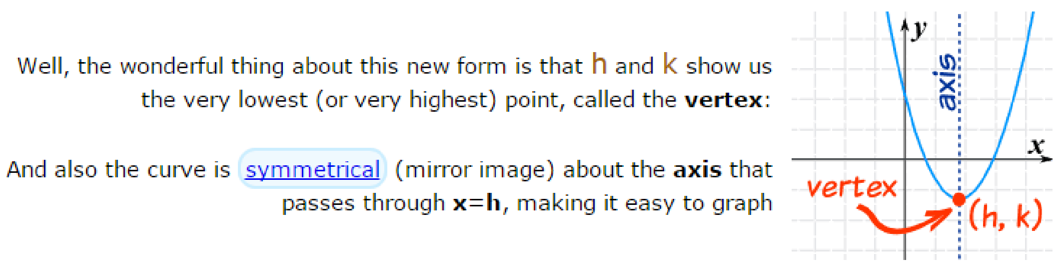

Figure 13: Quadratic Graph ("Graphing Quadratic Equations," n.d.)

Exponential $y = k + a{*}e^x$

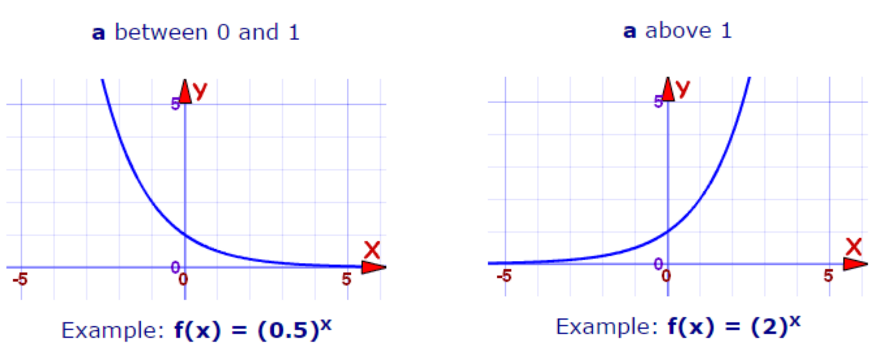

Figure 14: Exponential Graph ("Exponential Function Reference," n.d.)

Sine/Cosine y = a*sin(b(x - c)) + d

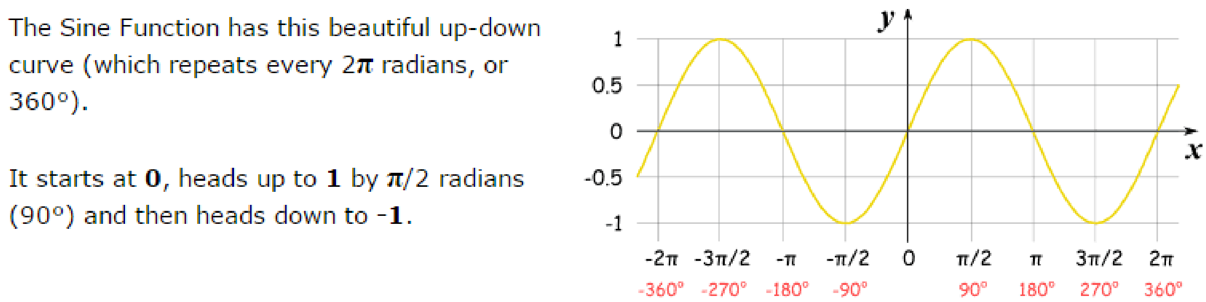

Figure 15: Trigonometric Graph (“Graphs of Sine, Cosine,” n.d.)

References

Allen, D. (n.d.). Improving Retention in Engineering by Incorporating Applications into Freshman Calculus. Retrieved August 10, 2015, from National Science Foundation website: http://nsf.gov/awardsearch/showAward?AWD_ID=1317310

Allen, D. (n.d.). UTeachEngineering: Training Secondary Teachers to Deliver Design-Based Engineering Instruction. Retrieved August 10, 2015, from National Science Foundation website: http://www.nsf.gov/awardsearch/showAward?AWD_ID=0831811

Carnegie, D. A. (2013). Improving retention rates at first year for modern engineering students. *2013 IEEE International Conference on Teaching, Assessment and Learning for Engineering (TALE)*, pp. 61-66. http://dx.doi.org/10.1109/TALE.2013.6654400

Exponential function reference. (n.d.). Retrieved August 14, 2015, from Math is Fun website: https://www.mathsisfun.com/sets/function-exponential.html

Foertsch, J., Moses, G., Strikwerda, J., & Litzkow, M. (2002). Reversing the lecture/homework paradigm using eTEACH web-based streaming video software. *Journal of Engineering Education*, *91*(3), 267-274. http://dx.doi.org/10.1002/j.2168-9830.2002.tb00703.x

Graphing quadratic equations. (n.d.). Retrieved August 14, 2015, from Math is Fun website: https://www.mathsisfun.com/algebra/quadratic-equation-graphing.html

Graphs of sine, cosine, and tangent. (n.d.). Retrieved August 14, 2015, from Math is Fun website: https://www.mathsisfun.com/algebra/trig-sin-cos-tan-graphs.html

Johri, A., Olds, B. M., Esmonde, I., Madhavan, K., Roth, W.-M., Schwartz, D. L., . . . Tabak, I. (2011). Situated engineering learning: bridging engineering education research and the learning sciences. *Journal of Engineering Education*, *100*(1), 151-185. http://dx.doi.org/10.1002/j.2168-9830.2011.tb00007.x

King, A. (1993). From sage on the stage to guide on the side. *College Teaching*, *41*(1), 30-35. Retrieved from http://www.jstor.org/stable/27558571

Maesumi, M. (2010, August 20). Online video lectures for calculus with analytic geometry I, MATH 2413. Retrieved August 5, 2013, from Online video lectures for calculus with analytic geometry I, MATH 2413 website: http://www.math.lamar.edu/faculty/maesumi/calculusone1.html

Marcey, D. J., & Brint, M. E. (2012, November). *Transforming an undergraduate introductory biology course through cinematic lectures and inverted classes: A preliminary assessment of the CLIC model of the flipped classroom*. Paper presented at 2012 NABT Biology Education Research Symposium, Hyatt Regency; Dallas, TX. Retrieved from http://www.nabt.org/websites/institution/File/docs/Four%20Year%20Section/2012%20Proceedings/Marcey%20&%20Brint.pdf

National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering*. Washington, DC: The National Academies Press.

Owusu, Y. A. (2006). Systems model for improving standards and retention in engineering education. *Journal Of American Academy Of Business*, *8*(1), 210-214. Retrieved from http://search.asee.org/search/fetch;jsessionid=26m9tbl9s18gq?url=file%3A%2F%2Flocalhost%2FE%3A%2Fsearch%2Fconference%2F25%2FAC%25202001Paper971.PDF&index=conference_papers&space=129746797203605791716676178&type=application%2Fpdf&charset=

Point-slope equation of a line. (n.d.). Retrieved August 14, 2015, from Math is Fun website: http://www.mathsisfun.com/algebra/line-equation-point-slope.html

Scherrer, C. R. (2013). Outreach emphasis on the human impact potential of engineering improves perceptions of underrepresented groups. *Journal of Women and Minorities in Science and Engineering*, *19*(1), 37-45. http://dx.doi.org/10.1615/JWomenMinorScienEng.2013005722

Science, technology, engineering, and mathematics talent expansion program (STEP). (n.d.). Retrieved May 1, 2015, from http://www.nsf.gov/pubs/2011/nsf11550/nsf11550.htm

Venable, W., McConnell, R., & Stiller, A. (1995). Incorporating mathematics in a freshman engineering course. *1995 Frontiers in Education Conference*, *2*, pp. 3c1.23-3c1.27. http://dx.doi.org/10.1109/FIE.1995.483136

Vincenti, W. G. (1990). *What engineers know and how they know it: Analytical studies from aeronautical history*. Baltimore, MD: Johns Hopkins University Press.

Wiggins, G., & McTighe, J. (1998). Understanding by design. Association for Supervision and Curriculum Development.

Woolston, D. C., Shook, K., & Wilson, J. (1995). Same problem, different solutions: Attempts at improving retention in engineering at a research vs. a teaching university. *1995 Frontiers in Education Conference*, *1*, pp. 3a3.1-3a3.5. http://dx.doi.org/10.1109/FIE.1995.483097

Vita

Mathew Deram grew up in Lincolnshire, Illinois, where he graduated from Adlai E. Stevenson High School in 2007. He earned his Bachelor of Arts in Mathematics and Physics from St. Olaf College in Northfield, Minnesota in 2011. He now lives in Leander, Texas, where he teaches AP Calculus, AP Physics C, and PSAT at Vista Ridge High School.

Email: mathew.deram@gmail.com

This report was typed by the author.