Exploring the Use of Student Taught Classes to Introduce New Technical Topics to Engineering Undergraduates

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***Abstract*— As engineering disciplines evolve, universities are challenged to continually incorporate new material into the undergraduate curriculum. Traditionally, the two primary methods of incorporating new material are to either change the curriculum of a specific class or hire a new instructor to teach a new class. In our paper, we introduce a new model for introducing skills and tools necessary for undergraduates to succeed in industry/academia via the Student Taught Classes program (STC). Overall, the STC program has been widely successful and far reaching. The popularity of the program can be attributed to the rigorous application process, flexible class structure, and broad impact that each of the seven classes taught have had over the past three semesters. When instituted in the right way, Student Taught Classes have the ability to add a new dimension to any undergraduate engineering curriculum.**

Keywords*— *Student Taught Classes, Engineering, New Material, internships, industry skills

I. INTRODUCTION

As engineering disciplines evolve, universities are challenged to continually incorporate new material into the undergraduate curriculum. Traditionally, the two primary methods of incorporating new material are to either change the curriculum of a specific class or hire a new instructor to teach a new class. With most universities facing increasingly tight budgets, hiring new faculty members is becoming increasing restrictive. Furthermore, changing the curriculum to include new technologies is often unfeasible, especially when a tool/software has a very specific application. Therefore, a technically inclined student taught classes program offers the flexibility and diversity needed in engineering schools to prepare undergraduates for the industry and academia.

The idea of student taught classes is not a novel concept. The University of Virginia (U.Va), and other schools across the country including Carnegie Mellon, Stanford, University of Texas at Austin, Oberlin, and others, already has university wide programs for undergraduates to introduce classes, most often in a seminar format. While their grading policies vary greatly, on average, these courses have around ten to twenty students and range from topics such as "Improv Comedy" to "Contemporary Love Poems" [2]. Furthermore, these courses serve to provide an opportunity for students to discuss topics of interest on a personal and reflective matter. These programs have been widely successful, yet have been confined to nontechnical topics.

Therefore, the U.Va Engineering Student Council within the School of Engineering and Applied Science (SEAS) experimented with creating a student taught classes (STC) program specifically tailored for engineering students with the mission statement to provide students an opportunity to learn skills not taught at U.Va, but that are useful for industry jobs, academic endeavors, or simply for personal enrichment in technical subjects. Past offerings have included "Introduction to Haskell," a class which taught students a programming language, and "Auto Mechanics" which provided a great opportunity for hands on experience.

II. BACKGROUND

The notion of peer-based and near-peer-based instruction is well known in the literature in many contexts. The broad idea of cooperative learning, in which students share their knowledge with each other using a goal of positive interdependence (see Johnson, Johnson, and Smith [3] and the references therein for a thorough overview of cooperative learning in STEM disciplines), shapes much of the modern active learning landscape. And the peer instruction model of Mazur [4] has popularized the approach of crowdsourcing learning in a supportive and collaborative environment. New tools like Learning Catalytics (Pearson, Inc. 2014) capitalize on the effective co-creation of meaning and understanding among students. Much of this work can also be understood in a constructivist framework as well, in which meaning is a socially-constructed entity among a group of learners (Vygotsky and many others [5]). Moreover, peer-based learning in both formal and informal settings has a long history via peer mentorship programs, living-learning communities, and other networks of students that exist outside the structure of a formal classroom.

While the STC initiative has some elements of these learning strategies, all of which are grounded firmly in the learning sciences and educational psychology literature, in practice the STC program is more akin to a mentorship model or the use of undergraduate TAs [6]. Upper division undergraduates share their knowledge with (near-) peers, in an environment more like mentorship and collaboration rather than one charged with the power dynamics of a professor-student interaction [7]. In many cases, undergraduate students possess expertise that faculty do not have (example: a specific programming language), are not interested in teaching (example: auto mechanics), or exist outside the usual confines of faculty comfort zone (example: brain hacks). These are nonetheless subjects of technical interest to engineering undergraduate students who value the opportunity to engage with the subjects in a well-structured way. These are the opportunities afforded by the STC program.

III. STC Program Organization

A. Program Structure

Unlike the generalized nature of student taught courses at other universities, the STC program was designed to encourage and support more unique, "hands-on" courses. Past research has repeatedly proven the success of "hands-on" components in the classroom, and our own surveys of first and second year students have shown a desire (82% in one survey of undergraduates in the Auto Mechanics course complained about a lack of opportunities) for a more "hands on" approach in their classes.

The classes are offered via U.Va's official course registry service (the Student Information System, or SIS) as one-credit, pass/fail offerings. Each class has a faculty advisor from the broad area being taught, and this faculty member is responsible for overseeing the course, for managing any issues that may arise in class, and for reporting final grades in the course. For enrolled students, these courses satisfy no degree requirements, and the instructors are not compensated or credited for their time.

The above attributes of the classes are intentional - the classes were designed to follow Thomas Jefferson's ideals on education, that it be passionate, uninhibited, and multifaceted. By not offering any compensation to the instructors, only those who are truly passionate and enthusiastic about their subject material apply. Similarly, because these classes do not affect students' grade point averages or fulfill any degree requirements, the only incentive to enroll is a true desire to learn and experience.

This creates an environment that encourages intelligent dialog and engagement between student instructors and students. At the end of most classes, instead of sprinting outside the classroom, students tend to stay behind, not only to converse with the instructor, but also to discuss the topic of hand with each other.

B. Selection Process

The selection process was created by Engineering Student Council, and is a constantly evolving process. Unlike a similar program in the College of Arts and Sciences [2], STC requires students to not only demonstrate mastery in their field, but also proven teaching proficiency prior to acceptance in the program. All SEAS students are eligible to apply by emailing the program directors with both their resume and proposed course syllabus. Once all the syllabi are collected, the program directors remove all syllabi that do not meet the instructor requirements or the program requirements. Following in line with the goal of the STC program, the program directors look for syllabi that have some combination of uniqueness, usefulness (from an industry or marketable skills standpoint), and hands-on components while not aligning too closely with courses already taught by faculty members in the University.

The remaining applicants are offered an interview with the program's faculty advisors, Dr. Archie Holmes and Assistant Dean Mary Beck. The thirty-minute interview consists of fifteen minutes of Q&A about past experiences with the subject material and teaching experience, and fifteen minutes of a sample course meeting. Historically, the sample "lecture" portion is where excellent instructors outshine the rest.

C. Post-Selection

After the instructors and classes for the new semester of the STC program have been selected, the program directors work with Engineering School staff, student instructors, and the faculty overseers of each course to set-up the time and room of the class in the official class registry. The syllabus of each course is then advertised across the Engineering School before the previous semester is finished in order to encourage students to enroll. Any capital or consumable resources required for the classes are coordinated and ordered in advance, and are paid for by the Engineering Student Council.

Once the new semester begins and final logistics are taken care of, the student instructors are given free rein to run the class. Everything from lectures and homework to grading is taken care of by the undergraduate student instructor with advice, but generally no explicit direction, from the faculty sponsor. Advertising for the course is done by the program coordinators through e-mail blasts and flyers. Instructors, especially those of Computer Science courses, are also encouraged to generate an online presence through course websites and posts on popular sites such as HackerNews and Reddit [8, 9, 10]. However this is not required, and completely dependent on the instructor.

IV. Case Studies of Recent STC Offerings

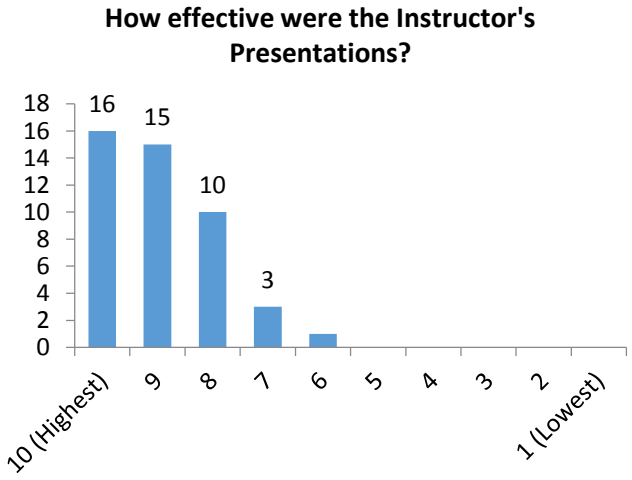
As of the end of the Spring 2014 semester, seven STC courses with topics such as Printed Circuit Board design and layout and Web Development with Node.js have been proposed, organized, and run. The courses presented below were the four courses offered by the program in its first year of existence. Overall the STC program has served more than 220 students within the Engineering School with classes in four disciplines: Applied Mathematics (APMA), Computer Science (CS), Electrical and Computer Engineering (ECE), and General Engineering (ENGR).

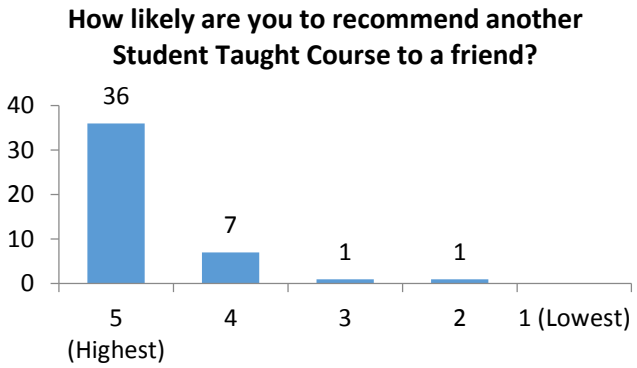
Following the end of each course, we ask students questions related to gauging the reception of the class and program as a whole. Three of the following five questions were asked to students in each of the classes, and the results of these questions are presented in each of the case studies: "How likely would you be to take another Student Taught Class?", "How likely would you be to recommend this class to a friend?", "How would you rate your experience in this class against others taught by faculty?", "Do you feel that is class adequately provided useful hands-on experiences that engaged with the lecture material and improved the class experience?", and "How effective would you say the student instructors were?".

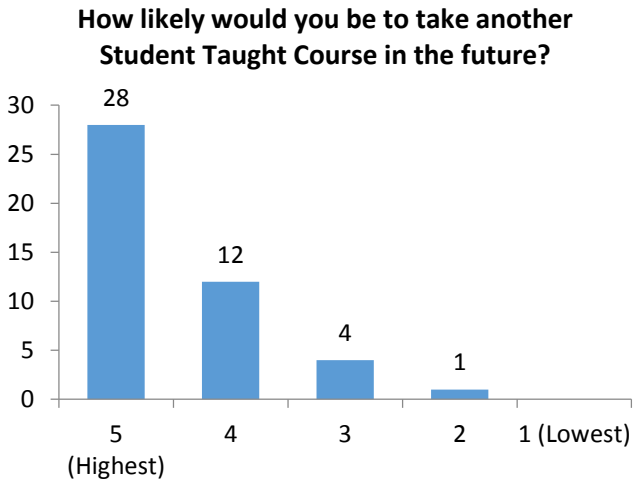
A. Introduction to Haskell (CS 1501)

The Introduction to Haskell course started out as the pilot course for the Engineering School's Student Taught Classes program. This course introduced basic concepts of functional programming through the use of Haskell, a powerful language that is rapidly gaining popularity among both industry and research. Topics in this class included pattern matching, type-classes, higher-order functions, list comprehension, lazy evaluation, lambda calculus, and monads. The class emphasized thinking functionally as opposed to imperatively. The instructor became proficient in Haskell as a result of his own interests and an industry summer internship with a multinational technology company.

The reception of the course among both online and offline students was overwhelmingly positive, and encouraged us to pursue the program for further semesters in the hopes of making it a staple of the Engineering School. The results of the student survey questions are shown below (responses from 45 out of 64 physical students in the course).







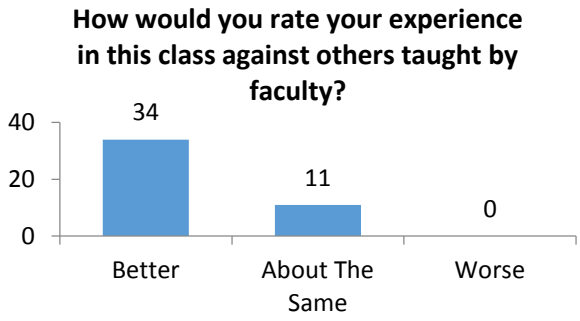
As a whole, the Introduction to Haskell course gained widespread recognition within the University and beyond [11]. By the end of the semester, the course had a presence of 64 students on campus as well as more than 1,000 online participants from over 50 universities. On average, more than 200 people would turn in the homework assignment every

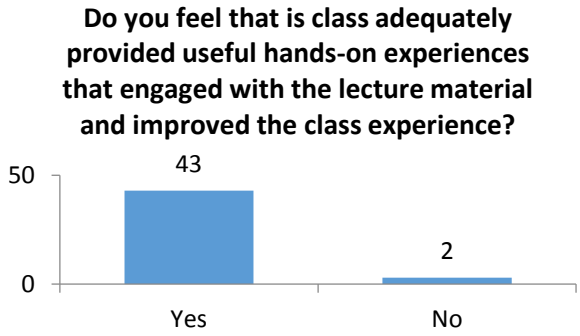
week. This course evolved, via word of mouth and social media, into a MOOC-like experience with large online participation.

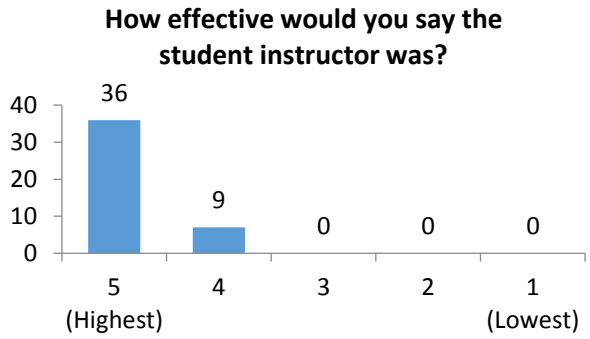
B. Graphics and Data Visualization (CS 1501)

The Graphics and Data Visualization was one of our three courses in the second semester, and the first semester as a formal program, of the Student Taught Classes program. This course was designed to equip engineers in all disciplines with a practical knowledge of graphic design in order to devise inventive new ways of interacting with data both on and off traditional charts. The course was comprised of short hands-on projects to teach the fundamentals of visualization and changed the way students see and communicate information.

As with the Introduction to Haskell class, the reception of the Data Visualization course was equally positive. The results of the student survey questions are shown below (responses from 45 out of 58 physical students in the course).





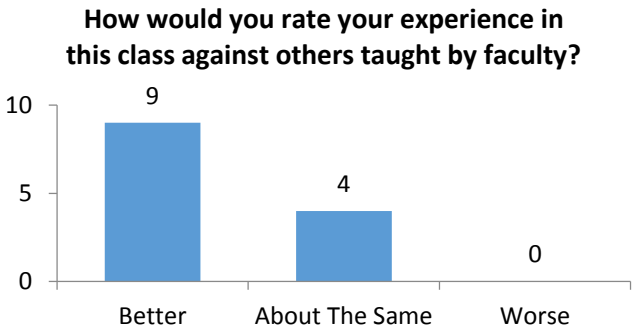


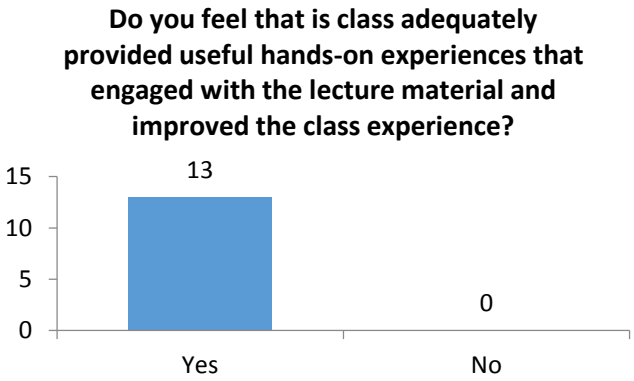
Through online portals, the Graphics and Data Visualization course gained the attention of a local Charlottesville, Virginia Data Visualization company, VividCortex. This company helped provide real data sets to the instructor for use in homework assignments in order to see what students could come up develop. Toward the end of the semester this same company offered the instructor a full time position and interviewed multiple students within the class for internship opportunities. Overall the class had 58 students enrolled through the University of Virginia as well as more than 150 online participants.

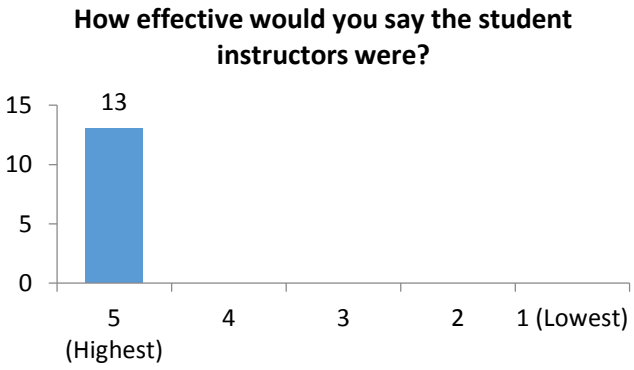
C. Auto Mechanics (ENGR 1501)

Auto Mechanics was the second of our three courses in the second semester of the Student Taught Classes program. This course taught students the basics of automotive maintenance. It began with an introduction to shop safety and tool usage, provided an overview of automotive components, and taught students how to perform basic automotive maintenance (all performed live on a real car). This course was taught once every two weeks, for 100 minutes each session (covering the same time basis as other one credit classes).

Due to the nature of the course and limited space, the Auto Mechanics class was significantly smaller than all of the other courses that were part of the program. This however seemed to be beneficial to the overall class, and in terms of reception the Auto Mechanics course can be considered one of the most successful courses in the Student Taught Classes program. The results of the student survey questions are shown below (responses from 13 out of 13 physical students in the course).





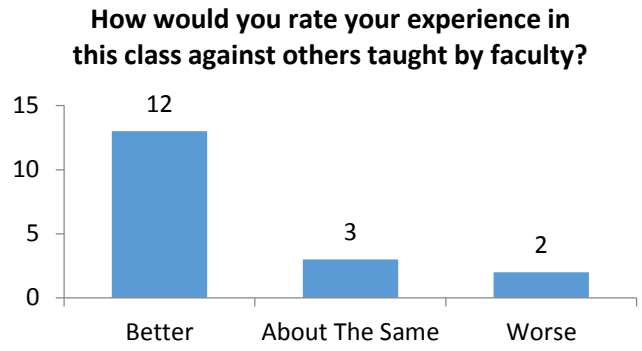


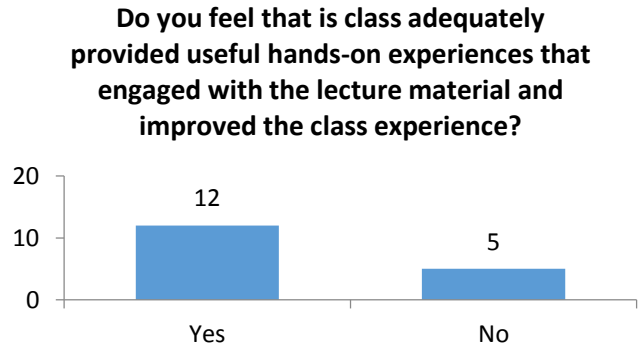
The Auto Mechanics course was the first course taught by two instructors, mostly because of safety and demoing requirements. It was also the first course to use Lacy Hall, a new University of Virginia Engineering School student projects facility meant to be a workplace for larger projects that need more open, garage like space. As highlighted above, the course was very well received by students within the class and gained popularity among the Engineering School community as a whole.

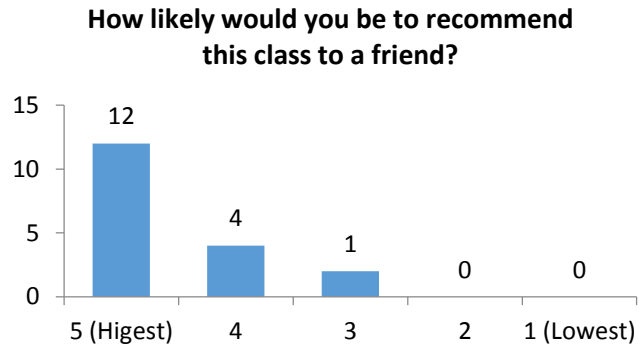
D. Brain Hacks: Scientific Success (ENGR 1501)

Brain Hacks was the third of our three courses in the second semester of the Student Taught Classes program. By leveraging research from Psychologists, Cognitive Scientists, and Behavioral Economists, this course explored applications of this research in everyday life with an emphasis on findings that most people have not heard. The course deviated from teaching more tangible engineering skills and instead looked to provide students with lessons that would help them improve aspects of their daily lives, such as working out and studying.

Unlike the Introduction to Haskell and Data Visualization course (both Computer Science courses), Brain Hacks did not have an online presence. The course however had a wide range of majors represented within the classroom, including students not in the Engineering School (such as Chemistry, Commerce, and History majors). The results of the student survey questions are shown below (responses from 17 out of 26 physical students in the course).







Since the end of the class, many students have claimed to be applying the studies and lessons that they learned inside the classroom.

V. Instructor Findings

The learning that happens with these classes does not stop with the students, but extends to the instructors as well. A common theme among student instructors has been the greater appreciation they have gotten for teachers and professors, and what it takes to keep a class engaging. They have all found themselves becoming better public speakers, and now have a very firm understanding on topics they previously thought they knew a lot about. For some, teaching a class has extended to better results in the classroom as well. During exit interviews, student instructors commented on the challenges faced: "effective learning requires student engagement, and this is the biggest challenge of all. The process allowed me to better see why I valued some classes I had taken in the engineering school more than others." Another instructor noted how he was impressed with the class, saying "the final projects my class turned in far exceeded what I would expect out of students in a one-credit class and I attribute this to how the class went." Overall the reception for this program on the side of the student instructors has been overwhelmingly positive, so much so that many of them have continued to help improve the program even after their classes are finished.

VI. Analysis

The structure of the Student Taught Classes program centers on the concept of "learning for the sake of learning"; since these courses do not count toward any degree requirements, we find that every student that signs up does so simply to learn something new. The willingness in participation helps lead to a more involved and better class overall, since every student wants to be there. Overall, this helped guarantee that those students who wanted to learn and participate, as opposed to those who would instead work on other assignments or would not pay attention, attended lecture. This is in contrast to typical elective courses offered by universities, where students are not always motivated by the subject (since many curriculums require a certain amount of elective courses) but still attend lecture.

By also providing relatively lenient requirements to pass the course (usually along the lines of attending 75% of the lectures and finishing 50% of the homework assignments), the courses create a stress-free environment for learning the material. This "buffer" in participation offered by each class gave students the ability to miss classes and/or homework during stressful times of the semester with little to no repercussions, but also helped get rid of any potential "free-rider" problem (students who would sign up for the class but not participate at all). This minimal requirement for 50% submission and 75% attendance results in extremely high course completion (student who "pass" the course)—this figure exceeds the typical experience in MOOCs which see 10% or less completion rates. The personalized component of the course—the instructor is their peer, and is presented deeply interesting material—contributes strongly to the high completion rate.

The reputation of the courses and student experience in the beginning of the program has also played a large role in the popularity of courses offered in later semesters. Because of the massive success of the Haskell course in the first semester of the program, students around the Engineering School were aware of the STC program and its benefits. This caused courses to fill up very quickly upon the initial wave of advertising, and even forced some classes to expand in size. However this worked in the other direction as well. We found that if one or two courses did not live up to expectations or reputation of the program, the entire program (and all the classes involved with it) is affected. Although it takes massive and consistent successes to slowly build the reputation of the program, one bad "wave" of courses has the ability to seriously hurt the program.

The Student Taught Classes model most easily translates to Computer Science courses. Because of the large amount of prevalent languages and tools, rapid pace in the introduction of new changes and products, and overall popularity of the field, the CS courses were always the fastest to fill up and among the most popular. CS consistently makes up a majority of class proposals as well. In addition, student instructors are able to leverage the online community to gain a presence beyond the University, helping add to the quality of the class and program as a whole. STC courses offered in other disciplines have the ability to be equally successful, but sometimes require more lab-based, "hands-on" instruction and slight changes in format (i.e. 100 minute lecture every other week to allow for more instruction time in the lab).

The most important component of the STC program is the student instructors because of the rare combination of technical and social skills required to teach an entertaining and worthwhile class. The success and sustainability of the program is completely based on the quality of the classes and therefore the quality of the student instructors. Finding the right students for the program, as well as pushing them to dedicate the time to teach a class, is a hard task to accomplish every semester. Furthermore, successful classes require not only skilled instructors, but also a well thought out syllabuses and appropriate topics. Because of this, instructors who wish to repeat a class topic in a later semester are not given old syllabuses but instead encouraged to organically develop their own.

The benefits of these classes also extend to the student instructors that teach them. Not only do these instructors gain invaluable experience in teaching and public speaking, but they also gain significant recognition. Multiple instructors have gained popularity with the classes they teach on online portals such as Reddit and Hacker News [8, 9, 10]. Instructors have also found corporate sponsors for their classes, which has also lead to some job offers. One instructor has also been approached by a publisher about a book deal based on the class he taught. As a whole, the STC program has also been

featured on U.Va Today (U.Va's official news publication) as well as the homepage of the U.Va website.

VII. Future Work

While the STC at U.Va's engineering school has been incredibly successful, there remains room for improvement in the upcoming semesters. One of the main challenges any program of this nature faces is outreach and recruiting. Only a select few students have both the technical knowledge and social capability to teach a class, and finding/encouraging these students to pursue the program takes a significant amount of advertising. As part of this advertising push, we are continually marketing to both student groups (such as the student chapter of IEEE) and to faculty members so that they may recommend or encourage top students to apply for the program.

We have also made better preparing instructors one of our top priorities for the future. Many students who apply for the program are not fully aware of the time commitment necessary to teach a class, and often times find themselves overwhelmed in the first few weeks of the semester. Although programs like U.Va's CavEd require student instructors to take a one semester class on teaching prior to instructing a class of their own, we find that this kind of time commitment is too much for student instructors from the engineering school. Therefore we hope to institute a one-day training session for future instructors, as well as access to previous instructors, so as to provide the same sort of guidance as the CavEd teaching course without requiring a massive time commitment.

In order to provide a more unified front for the STC program as a whole, a website is currently in development. The goal of this website is to be a centralized repository for all the courses taught in the program, including course materials. We expect to populate the website with as much content about each course as possible so that the benefits and knowledge provided by the classes can continue to be reaped after the course is finished.

As part of the spring 2014 semester we introduced three new courses as part of the STC program, including our first course in Electrical Engineering (ECE) and Applied Mathematics (APMA). Although the reception among students and faculty has been positive for these courses, formal data is yet to be collected on these classes and how they fared compared to our previous courses.

As with any program, the STC program is constantly adapting to the interests of the student body as well as the needs of the Engineering School. While courses in areas such as CS and ECE have been introduced and well-executed, it is essential to explore student taught courses in other fields as well. Aspects such as course sizes and amount of instructors are continually re-examined in order to find an effective balance between the number of students in the class and the quality of the class. As a whole, the STC program should be constantly analyzed and adjusted to ensure continued improvement.

VIII. Conclusion

The UVa engineering implementation of a Student Taught Classes program provides an innovative and refreshing way to introduce new material to the engineering student body. The structure of the courses, one non-degree requirement pass/fail credit with relatively lenient requirements, provides a stress-free environment that is more conducive to the overall learning and is essential to the success of each class. The application process for instructors/classes plays another important role in the overall program, as the capability and preparedness of each instructor can be directly correlated to the success and popularity of each course.

However as a whole, it is imperative to keep the overall structure of the program as dynamic and receptive to the student body and needs of the Engineering School as possible. What is considered "new" in engineering is always changing, and therefore it is the job of the program directors to ensure that the STC program is adjusting to all of the changes.

Overall, a flourishing Student Taught Classes program has the ability to boost the knowledge of the student body, provide top students with the ability to showcase their talents, and bolster the reputation of the engineering school and university as a whole.

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