# Beyond the Box: A Contribution to Changing the Engineering Educational Paradigm

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**Abstract -** The engineering educational paradigm is changing. Recent literature shows an increase in classes that provide realistic design challenges early in an engineering curriculum, a trend that is linked to increases in student motivation and retention rates. Inside the Box (ITB), a section of ENGR 162 Workshop, the Introduction to Engineering class required of all First-Year[2] (freshman) engineering students at the University of Virginia, is a class that is helping to set these new trends. The goal of this two-part thesis project was to explore the ways in which the ITB program is contributing to changing the engineering educational paradigm. The first part of this project involved the creation of a new website to publicize the ITB program and provide access to course materials so that the ITB program might be implemented elsewhere. The second part of this project involved creating and conducting two surveys: the ITB Alumni survey which was distributed to four classes of program alumni, and the Engineering Design Experience (EDE) survey, which was distributed to all Second through Fourth-Year engineering students. A comparison of the ITB Alumni and EDE survey data revealed that the experiences of ITB program participants had a greater impact on increasing student enthusiasm and motivation to pursue engineering than did the experiences of students in other ENGR 162 Workshop sections.

*Keywords:* Inside the Box, ITB, University of Virginia, SEAS, ENGR 162

## INTRODUCTION

Inside the Box (ITB), a section of ENGR 162 Workshop, the Introduction to Engineering class required of all First-Year (freshman) engineering students at the University of Virginia, is a class that offers students a multidisciplinary open-ended design experience in their first semester. The purpose of this thesis project was twofold: first, to create a website to publicize the ITB program, and second, to study the impact of this class on the undergraduate engineering experiences of its participants. Specifically, engineering undergraduates were surveyed to determine if there was any measurable difference between the attitudes towards engineering developed by students that participated in the ITB program and those developed by students in other ENGR 162 Workshop sections.

### Problem Background

The brute force method of grinding students through a rigorous and highly theoretical engineering curriculum is no longer as popular or effective as was once believed. As Drexel University professor and engineering education pioneer Eli Fromm [1] has observed, it appears that "a significant and sustainable culture change and paradigm shift is taking place in engineering education," as more and more schools are offering classes that connect students with engineering in a broader context. The University of Virginia School of Engineering and Applied Science (SEAS) begins teaching the many responsibilities of an engineer from the beginning of a student's development in required first year classes such as Science, Technology and Society (STS) 101, and the aforementioned ENGR 162 Workshop.

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[2] The University of Virginia does not use the terms "Freshman" "Sophomore" etc. Students are instead designated by "Year" at the University.

In the section of ENGR 162 titled "Inside the Box" (ITB), students participate in a semester long project that tasks teams of four to five engineering students to design, build and ultimately perform five special effects for an original ten-minute play written and directed by students in the University's Drama Department. Over the course of the semester, engineering students learn not only the technical skills required to build special effects, but also participate in the full engineering design process. 2007 marked the four-year anniversary of the first ITB class, and there are now ITB program alumni in every major and every undergraduate year of the School of Engineering and Applied Science. This project arose at a unique time that offered clear opportunity to examine the impact that introducing multidisciplinary team-based learning experiences such as ITB early in an engineering curriculum has on students' future engineering endeavors.

**Project Scope**

The ITB program website was created to provide a clear, organized, and complete resource for those seeking to learn about the class. The ITB Alumni and Engineering Design Experience surveys were administered to learn more about students' opinions of their engineering education. The data presents a compelling case not only for broad change to the engineering educational paradigm, but for the potential of classes such as ITB to help create this positive change. As this project focuses on the ITB program and early design experience, it is beyond the project scope to propose extensive modifications to the existing system for middle and upper level engineering classes. The project results, however, do contain interesting statistics that serve to highlight areas that can be targeted for improvement through future work.

## PART I: THE INSIDE THE BOX PROGRAM WEBSITE

The idea for the Inside the Box Program website originated nearly four years ago at the time of the inception of the class, but was not completed and implemented until this thesis project. The website is composed of five pages: Home, About the Project, Resources, Photo Gallery, and Useful Links. It was created using Adobe Dreamweaver and is located on the SEAS server, and can be accessed at www.seas.virginia.edu/academic/insidethebox. Each of the pages contains links to the SEAS homepage, the UVA homepage, the Drama Department homepage, as well as contact information for Benjamin Kidd, the creator of the ITB program.

The Home Page, pictured in Figure 1 to the right, welcomes visitors with a brief introduction to the project, directions for navigating the site and ITB program news.


*Figure 1. Inside the Box Program Home Page*

The page titled "About the Project" presents a more in depth discussion of the program including history, project details, and academic publications related to this program. This page also contains a section titled "Is Inside the Box Right for You?" for visitors who are exploring implementing their own ITB program.

The "Resources" page contains reusable learning resources, that is, essentially every file that could possibly be beneficial to someone setting up their own ITB program including a sample syllabus, handouts and forms, assignments, lectures and the reports and presentations of past ITB teams.

The "Photo Gallery" contains pictures of various points through the semester during each of the past four ITB classes, from in-class activities to random evenings in the lab, to the final play performances. Each thumbnail opens in a new window for ease of viewing.

The section titled "Useful Links" contains a list of links to vendors and other websites that the ITB team has found useful for procuring materials and information over the past four years. This list is meant to serve merely as a suggestion, not an endorsement, a fact that is clearly stated on the page.

Eli Fromm [1] champions transforming developments for a broader audience, "beyond those who have had intimate development contact and direct application". A comprehensive class website for the ITB program benefits both the broader educational community and the course developers here at the University. Making available the

materials required to implement a program such as this creates the opportunity to participate in changing not only the engineering educational paradigm, but STEM (Science, Technology, Engineering and Mathematics) education at many levels.

**Website Implications**

The ITB program is designed in such a way that it can be scaled up or down according to the goals of the instructors. It is hoped that website users will not just be class participants or professors at fellow universities, but also any member of the education community, including high school or primary school teachers, and other creative thinkers. The section of the website titled "Is ITB Right for You?" was designed with this broad audience in mind. In order to help interested parties determine if, when, and how to implement their own ITB program, this section highlights a few things that should be considered beyond the reconfiguration of the UVA ITB syllabus to fit their own institution's academic calendar: namely, the resources available to them, and the ramifications of implementing an ITB program at their own institutions. Not only does the ITB program require a smaller class size (optimally less than 40 people), but it requires funding (each engineering team receives a $50 budget), an engineering teaching team with an array of mechanical and electrical skills (as well as much time to devote to office hours), and a drama department interested in multidisciplinary collaboration. At the time of the completion of this thesis (March 2008), the ITB teaching team has been contacted by the Director of the Engineering Design Program at Pennsylvania State University (Penn State) to assist with their efforts to modify the ITB program to meet the goals of their individual institution. As of December 2008, Penn State has successfully offered a class titled "In the Spotlight" (http://sites.google.com/site/edsgn100hinthespotlight/Home) modeled after ITB.

## PART II: SURVEYS

The second part of this thesis project involved the creation and distribution of two surveys, the ITB Alumni survey to four classes of ITB program participants, and the Engineering Design Experience (EDE) survey to all SEAS Second through Fourth-Year students. These surveys were created and distributed using the free online survey program SurveyMonkey. Both surveys focused on students' experiences in ENGR 162 Workshop, the Introduction to Engineering Workshop class required of all First-Year engineering students at the University of Virginia

The Inside the Box Alumni survey was sent to four classes (120 students total) and had a 42.5% response rate (68/120). The survey was two parts and ten questions total. Response rates by year are presented in Table 1. Two respondents declined to identify their academic year.

| First-Year Students (SEAS '11) | Second-Year Students (SEAS '10) | Third-Year Students (SEAS '09) | Fourth-Year Students (SEAS '08) |
|---|---|---|---|
| 19 Responses | 22 Responses | 18 Responses | 7 Responses |
| 28.8% of survey responses | 33.3% of survey responses | 27.3% of survey responses | 11.0% of survey responses |
| 50.0% class response rate | 52.4% class response rate | 45.0% class response rate | 17.5% class response rate |

*Table 1. ITB Alumni Survey Response Rates*

The differences in response rate may have been impacted by such factors as how fresh ITB program experiences are in the minds of alumni, the varying amount of demand students have on their time as a result of major and academic year, as well as the limited number of students who actually read all emails that come from the University administration.

Several questions asked respondents to indicate the degree to which they agreed or disagreed with different statements. Responses were assigned a rating value: 5 for Strongly Agree, 4 for Agree, 3 for Neutral, 2 for Disagree, and 1 for Strongly Disagree. This question type, called Likert, is commonly used in social research. To the statement, *"The open ended design project format of the Inside the Box class was more effective at engaging me with engineering than the formats of other classes I have taken in the E-School,"* 89.6% or 60/67 responses indicated strong or general agreement, and 7/67 or 10.4% of participants responded "neutral." The average rating for this question was 4.34, and it was skipped by one respondent.

The response to this question was in keeping with trends among engineering programs world-wide, namely, that students find inspiration and motivation in hands-on design experiences. One survey participant commented

> I feel that [the class format] encouraged me to explore creativity that I had not explored before. It made me make things work when it did not seem like it would work. In that sense it gave me a stronger appreciation for taking initiative and working through things in engineering.

Interestingly, this respondent followed up this statement with the observation that "most of my other engineering classes focus more on the technical side, so I feel that they are [not] really capable of being compared to this class." This comment highlights the fact that students still identify a difference between learning and applying technical concepts, an indication of the work that remains to be done by educators to synthesize the two and present students with more complete engineering experiences.

52.5% or 35/67 respondents agreed that *"Working on a project as part of a multidisciplinary team helped me develop a better understanding of the roles and responsibilities of engineers."* Comments made in response to this question, however, indicate that students felt that the ITB class did not provide as much exposure to the engineering profession as it did provide opportunities for them to develop valuable team work skills. 73.7% of Third and Fourth-year respondents indicated that the biggest impact that participating in the ITB program has had on their subsequent undergraduate experiences was that they learned early how to work in groups, an invaluable skill not only in school but in society today.

One unique aspect of the ITB program is the involvement of undergraduates in the teaching team. This began in 2005 when the author (then a Second-Year student) joined Professor Marshall and Benjamin Kidd, and continued in 2006 with the addition of William Barnhardt (Mechanical Engineering 2010). Both undergraduate teaching assistants (TAs) are program alumni, are involved in lectures, and participate in grading and office hours. This allows much opportunity for interaction with students, and it has been the policy of the teaching team to be available as a resource to students both for ITB related and non-class related issues. This policy comes from a desire shared by every educator: the desire to see students succeed.

The presence of undergraduate TAs not only distributes the work required to run a class of this scale across the teaching team, but also creates a unique and valuable resource for class participants. Survey results confirmed that students appreciate this aspect of the ITB program. 84.2% of survey participants responded *"my ITB experience benefited from the presence of undergraduate TAs,"* 71.9% viewed the undergraduate TAs as an accessible resource for all questions, and 64.9% replied *"having accessible undergraduate TAs in some of my other classes would be helpful."* The implications of these particular results will be elaborated upon in Section 5.3, Recommendations for Future Work.

**Comparison of Engineering Design Experience and ITB Alumni Survey Findings**

The Engineering Design Experience (EDE) survey was sent to all SEAS Second, Third, and Fourth-Year students. Response rates are presented in Table 2 below.

| **Second-Year Students (SEAS '10)** | **Third-Year Students (SEAS '09)** | **Fourth-Year Students (SEAS '08)** |
|---|---|---|
| 74/530 Possible Responses | 51/440 Possible Responses | 97/453 Possible Responses |
| 14.0% | 11.59% | 21.41% |

*Table 2. EDE Survey Response Rates*

Though the EDE survey was administered to obtain comparison data, the results are capable of standing alone as interesting findings. For the purpose of this project, however, data will be examined in comparison to the ITB survey findings and thus the following discussion focuses on four of the five questions asked on both surveys.

When asked the reason for choosing the particular section of the ENGR 162 Workshop that they were enrolled in, the overwhelming response from students (>73% for all sample groups) was *"I liked the schedule timing."* This answer reflects the fact that during Summer Orientation, rising First-Year engineering students choose from a number of pre-set schedules. Occasionally in past years, students have been informed of the theme (or lack thereof) for their Introduction to Engineering class prior to registering for a schedule. Unfortunately, no record has been kept to indicate whether or not students were consistently briefed on the options available to them prior to registration. Results indicate that ITB Alumni and current Third-Year students may have been moderately more informed than other classes as 31.3% and 25.5% of participants respectively responded that *"I had heard*

*about the project and was very interested in the topic."* It is hoped that the existence of the ITB program website will publicize the program and further attract interested students, if not to the program, at least to the many opportunities available to SEAS students.

Each survey asked participants to choose from several statements describing the relationship between their ENGR 162 Workshop experience and their decision regarding the continuation of their engineering education. 50.7% of ITB Alumni survey participants answered *"this class had a positive impact on my decision to pursue an engineering education"* as opposed to an average of 37.3% for the three academic levels represented by the EDE survey. As it is often difficult to obtain feedback from students who may not have strong feelings (either positive or negative) towards a class, responses tend to represent more extreme opinions. The views of ITB alumni are best expressed with comments such as "I was considering giving up on engineering, however, this class helped keep me on track and inspire[d] me to continue in my studies" and "this class made me love the design process before I even understood what it was."

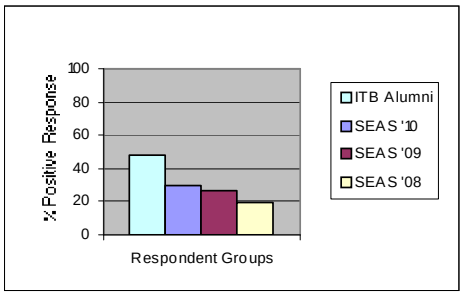


*Figure 2. "ENGR 162 Workshop motivated me to continue studying engineering."*

When asked "*how has your ENGR 162 Workshop experience impacted your undergraduate experience?"* 60.5% of ITB Alumni survey participants and 36.9% (averaged) of EDE survey participants responded *"it increased my enthusiasm for engineering from the beginning of my education."* 47.7% of ITB Alumni survey participants and 29.3% of Second-Year EDE participants answered *"[my ENGR 162 Workshop section] motivated me to continue studying engineering."* As can be seen in below in Figure 2, this number decreased to 26.7% for Third-Year students and 19.5% for Fourth-Year students. These differences can be attributed to the duration of time that has passed since the students' ENGR 162 Workshop experience, as well as the different projects associated with each section. Regardless of section or academic year, survey participants reported that ENGR 162 Workshop helped them make good friends (arguably a trait of most 100 level classes), and, as mentioned earlier, taught many how to work in groups.

Finally, students were asked indicate the degree to which they agreed or disagreed with the following statement: *"The experiences of my ENGR 162 Workshop section inspired and encouraged me as a First-Year student and continue to motivate me in my engineering pursuits."* Responses rates are displayed in Figure 3.

35.3% of ITB Alumni survey participants responded "Strongly Agree" as compared to an average of 6.83% for EDE survey participants. The average for those who responded "Agree" was comparable for both surveys, however, with EDE surveys reporting 29.1% and the ITB Alumni survey reporting 29.4%. The average rating for this question was 3.04 (neutral) for EDE survey participants and 3.87 (agree) for ITB Alumni survey participants. These statistics appear to confirm what ITB founders, Electrical Engineering PhD candidate Benjamin Kidd and Electrical Engineering Professor Paxton Marshall [2] reported in their first publication relating to the ITB program, that "involving students in team projects which require active and collaborative synthesis and decision making, and which provide a real world context to which students can connect" creates a more effective learning experience.

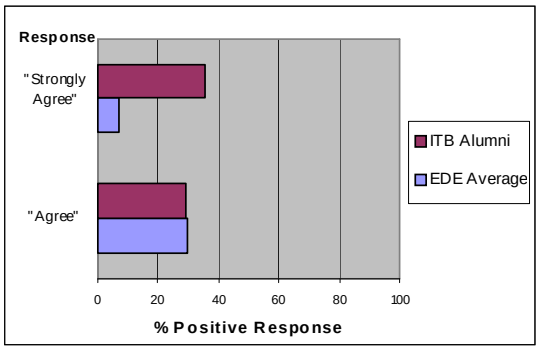


*Figure 3. "The experiences of my ENGR 162 Workshop section inspired and encouraged me as a First-Year student and continue to motivate me in my engineering pursuits."*

Regarding at-large design experiences available to SEAS students, 18.8% of Fourth-Year respondents to the EDE survey believe that "*there are fantastic opportunities [in SEAS] to engage in engineering design and I have taken advantage of many,"* as compared to 6.8% of Second-

Year respondents. This difference can be attributed to the length of time that students have been enrolled in SEAS. Still, this is an indication not only that more remains to be done at every level to integrate learning and applying concepts, but that existing opportunities must be better publicized.

The results of both surveys do not present anything unexpected, but rather reinforce that the ENGR 162 Workshop program is, overall, a valuable experience for students. Workshop sections such as ITB that focused on one semester long design project by and large received more positive feedback, indicating that students appreciate the level of creativity and complexity involved in these projects. From informal conversations and witnessing four years of ITB program participants, it was expected that the ITB alumni survey would support and attest to the claims that the author, and the engineering education community have made: that early introductions to the engineering design process increase motivation, enthusiasm, interest, and retention in engineering programs. Looking at the ITB alumni survey data alongside that of the EDE survey, it becomes clear that while exposure to design is important, it is not the only thing that makes a difference to students. Project type, guidance from instructors, course structure, and team dynamics all contribute to what students take away from each experience and to how those experiences color their opinions of engineering.

## PART III: CONCLUSIONS

It has been observed many times, and is proved again with this thesis, that early exposure to engineering design increases student motivation and therefore retention rates. Though the surveys administered for this project were, in terms of social research, created, conducted, and analyzed at a very basic level, the findings are consistent with those of similar studies. The fact that the ITB program continually receives higher marks than other ENGR 162 Workshop sections is gratifying, yes, but it is the implications of the results that are important. The results of this study not only strengthen arguments for continuing to change the engineering educational paradigm, but prove that the ITB program is viable method of doing such.

Today, fewer and fewer colleges and universities are continuing to take what Rice University Professor James Young calls the "eat your spinach" approach to engineering education [as quoted in Halford, 3], but there is still no "one-size-fits-all" transition paradigm [Splitt, 4]. It is up to each institution to determine how they will offer courses that provide early design experiences and how they will cultivate the engineers of tomorrow. Sharing the methods and philosophy of the ITB program through the results of this thesis project provides another resource for engineering institutions attempting to create their own transition paradigm.

As one ITB 2007 participant said "Honestly, this has been the best course that I have taken this semester. I have learned a lot about myself, people, teamwork, [basic building skills] and leadership." While this feedback signifies a job well done, we as educators must be aware that classes such as ITB often heighten the differences between classes and teaching styles for students. The potential of the ITB program to increase retention rates lies in the fact that in addition to offering a challenging and fun project, the instructors are able to develop relationships with individual students, addressing how students feel about college and life as an engineering student, not just how they perform academically. An unintended and potential consequence of the ITB experience, however, is the creation of falsely high expectations. It is possible that program participants could be disappointed by future engineering classes, especially those taught in a more traditional manner. If this is the case, the spread of the ITB program could backfire, resulting in student frustration and disinterest in other classes, causing a decrease in retention rates rather than the hoped for increase. That being said, 69.4% (averaged) of EDE survey participants feel that *"[their] classes are a good mix of hands-on design and other coursework,"* which confirms that SEAS is responding well to changing trends and continuing its strong tradition of engineering excellence.

### Recommendations for Future Work

This project is just one of the many initiatives dedicated to changing the engineering educational paradigm. One important aspect of continuing the work of this project is a responsibility that falls to the ITB teaching team: website maintenance. Updating the program website will be an important part of ensuring that the website remains a relevant resource. Tracking visitors to the program website would be one way of ensuring that the most relevant information is posted. This could be done through a simple survey on the program Home page in the already existing section titled "Hoo Are You?" and would provide information that would allow the website content to be tailored and made as useful as possible. Additionally, basic information regarding the number of new and returning

users, as well as when the website is accessed most can be tracked using an invisible hit counter such as the one available free from www.StatCounter.com. Similar to the summary analysis service offered by SurveyMonkey, this website also provides basic analysis free to registered users. When, and if, more ITB programs are begun, the addition of a message board section to the website enabling new programs to network and share experiences and advice could also foster community and creativity. These communities would provide opportunities for conducting more advanced social research, examining larger and more diverse populations over a longer period of time.

It was beyond the scope of this project to examine and propose modifications to middle and upper level engineering classes; however, these classes are no less important than early experiences, and addressing them is critical to the continuing evolution of the engineering educational process. As the ITB Alumni survey results showed, the ITB program has benefited greatly from the presence of undergraduate teaching assistants, and it is reasonable to imagine the same amount of success could be possible with other classes. Introducing undergraduate TAs into Second and Third-Year classes is worth exploring as it could provide more peer mentoring opportunities, another trend that has been linked to improving the student experiences.

We are living in a very exciting and crucial time for engineering education. Not only must we attract more students to engineering, but we must better engage and support those who have already chosen to pursue an engineering degree. The true challenge of changing the engineering educational paradigm is finding the proper balance between engaging projects and fundamental theories. As different institutions develop and share transition paradigms, we will continue to improve our ability to find this balance, and we will continue to improve our ability to educate the type of engineers that will be needed to serve society in the future.

## REFERENCES


[1] Fromm, Eli, "The Changing Engineering Educational Paradigm," *ASEE Journal of Engineering Education, 92*(2), 113, 119.

[2] Kidd, Benjamin & Paxton Marshall, "Inside the box: Teaching Engineering Design Through Theatrical Special Effects," *Paper presented at 2005 ASEE Annual Conference.* Portland, Oregon: University of Virginia, 3.

[3] Halford, Bethany, "Engineering for Everyone," *PRISM Magazine, 2004, 14(4),* 26.

[4] Splitt, Frank, "The Challenge to Change: On Realizing the New Paradigm for Engineering Education," *ASEE Journal of Engineering Education, 2003, 92*(2), 181-187.


## BIOGRAPHICAL INFORMATION


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Kristin graduated in May 2008 from the University of Virginia with a Bachelor's Degree in Civil Engineering. This research was conducted to indulge a passion for education and to fulfill the requirements for her undergraduate thesis. She is currently employed as a Project Engineer for Balfour Beatty Construction in Fairfax, Virginia, and tries to keep current with ASEE news and events to maintain ties to academia and the engineering education community. ITB continues to be a First-Year student favorite at UVA and questions about current projects should be directed to Paxton Marshall, ppm5y@virginia.edu.