Optimizing Summer Externships

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Abstract

Summer immersive experiences provide students the opportunity to explore the limits of their engineering education and develop a depth in a field of study. For institutions that centrally manage these experiences, ranging from experiments conducted at other academic locations to research and development with industry partners, to procurement and development with government laboratories and program offices, it can be difficult to ensure that all participants are receiving quality experiences. A survey had previously been administered to capture the value of student's summer immersive experience based on ABET Student Outcomes. Much of the data proved inconclusive due to the structure of the questions. However the data was used as a baseline for follow on research and guided the development of future surveys.

Following the summer of 2013, a new survey was administered to students majoring in aeronautical, electrical, and mechanical engineering at three different colleges who had participated in institution-sponsored immersive experiences. The goal of the survey was to determine why students chose their summer experiences, what made these experiences successful, and how to improve experiences in the future to maximize return on investment. Success was measured not just in whether they experienced the ABET Student Outcomes (a)-(k) but to what level they were challenged in those domains. The results of the survey will be used next summer to influence which experiences are offered and refine how students are paired with a summer experience.

The field of engineering education is constantly being refined. It is no longer enough to just be able to solve equations and apply principles of engineering. Engineers need to be able to work in multidisciplinary teams; delve into their specialty while also understanding how their focused work integrates into the overall system; and communicate ideas to both technical audiences and product consumers [**1**,**2**]. These goals can be difficult to accomplish within the confines of a classroom. Often this is left to industry to complete after the student has graduated, while academia focuses on the technical skills and fundamental knowledge. However, if students have the opportunity to participate in out-of-class experiences such as cooperative education programs, internships, and externships, they develop better analytical and group skills and become a more rounded engineering graduate [**3**].

Many internships and externships fall to the responsibility of the student to coordinate. This provides the student personal responsibility for their education and relieves workload from the faculty. Unfortunately this scenario does not work for some institutions where students have additional summer requirements for graduation that interfere with designated durations for internships. This is why externships – shorter summer employment experiences that normally last only a few weeks – are more practical for these institutions than internships which often last a few months. This requires more direct involvement from faculty in the process by establishing relationships, coordinating the financial and logistical administration of the summer immersive experience, and assigning students to the experiences.

While this adds to faculty workload, there are some benefits to an engineering program being directly involved in the internship/externship process. First, it creates an opportunity for students that would not normally have a chance to do a summer internship or externship. With limited time during summers due to requirements that are not finalized until mid-spring, there is not enough time for students to coordinate their own internship or externship. It also allows the faculty to influence which internships and externships the students participate in. While sponsoring agencies have a good idea of which intern would best support their organization, faculty from the student's engineering program have a better idea of which summer experience would best support and enhance the student's education. Finally, it allows faculty to apply academic credit to a student's summer work by creating a structure and means to evaluate performance [**4**].

Research has been conducted through numerous sources as to the educational benefits afforded an engineering student participating in some out-of-class work experience, be it a cooperative education program [**5**,**6**], internship [**4**,**7**], or advanced undergraduate research in engineering [**8**,**9**]. Some utilize the Accreditation Board for Engineering and Technology (ABET) Student Outcomes to assess performance of individuals during internships [**10**,**11**] while others use interviews to gather perceptions of a sample of students' experience with internships [**12**].

This paper attempts to identify the keys to a successful externship experience and how to best match the right student with the right externship. Survey data was gathered from four different ABET accredited engineering programs (one aerospace, one electrical and two mechanical) from three service academies (the United States Military Academy, the United States Naval Academy, and the United States Air Force Academy). The three colleges have a small student body with only about 4,500 students per academy, but they have strong reputations for developing outstanding engineering programs. The information from the surveys was broken down statistically to ascertain correlations in order to identify what led to successful experiences and how the engineering programs can focus efforts to improve success in the future.

Externships

The externships provided by the three institutions are highly encouraged by their respective departments for increasing the depth of understanding in the field of study. Students have on average 11 weeks during the summer in which to complete an externship. However, due to other graduation requirements, the majority spend less than four weeks with the most frequent duration being three weeks. The opportunities afforded to the students are diverse and categorized into three general areas: 66% worked at a government lab/agency, 24% worked at an industry lab or facility and 10% worked at another academic institution.

For externships to be successful, planning begins a year in advance. The fall prior, faculty spends their time identifying where they want to focus their efforts and coordinating new experiences. Externships that were conducted the prior year are contacted to reaffirm their commitment for the next year. Two page proposals are created as both a justification of the expenditures and a guide for students to decide which projects to pursue. While some projects are earmarked for specific students as they tie into ongoing research either before or after the externship, others are assigned based on student interest and faculty selection. Students enter their preferences and faculty place students in an externship based on GPA, prerequisites, and field of study, with GPA often being the primary factor. The exception would be the more practical externships that do not challenge students in the field of engineering but provide a practical sense of possible future jobs. Often these are in the field of aviation testing and acquisition. GPA still plays a role in selecting students for these externships, but a desire to actually enter that career field following graduation is also a requirement.

Though similar in limitations and general setup of the programs, there are noticeable differences in focuses for the programs in the different departments. The aerospace engineering and mechanical engineering programs had a strong focus (66% and 40% of projects, respectively) on projects that directly tied to research done at the school either the previous year or the year following the summer externship. However the electrical engineering program had only 18.5% of their projects tied to ongoing research during the school year. While one institution had half of their externships at a government facility and a third with private industry, the other two institutions had their students work almost exclusively with government agencies.

The electrical engineering program had modified its Student Outcomes while the other three programs adopted the standard ABET Student Outcomes (though reworded) to evaluate. The electrical engineering program combined ABET outcomes c, h, and j into a single outcome. This change in outcomes was designed to create a more efficient and sustainable assessment process.

The purpose of this survey was to provide departments with information to improve three key areas to their externship experience: 1) Student satisfaction with the experience, 2) Student learning from the experience, and 3) Student perception of the degree to which the externship experience complemented the student's undergraduate engineering program. The first two goals are often linked together, though measured by different means.

The externship program is completely voluntary and therefore students must gain some satisfaction from participating in the program, or word will spread and students will stop enrolling. Also, when students are enjoying themselves, they are much more receptive to learning [**13**]. Accomplishing this goal was based on students' response to their ability to accomplish their goal during the externship.

The learning aspect from the experience is ultimately what is desired from the engineering programs. Establishing, managing, and evaluating externships takes a considerable investment of time from faculty. Therefore, engineering programs that participate in these programs want to ensure that students are maximizing the learning opportunities from these programs; in effect, maximizing their return on investment.

The third goal seeks to improve the way in which externships fill niche needs in an undergraduate engineering curriculum. Regardless of the program, there are some aspects of an engineering education that are not conducive to learning in a classroom. As most courses focus on specific topics (thermodynamics, computer aided design, strength of materials, etc.) it can be difficult to demonstrate total system integration of multiple disciplines with diverse teams. Often, real world applications are limited by assumptions made to simplify problems so that the analysis can be more easily performed in class. While many externships can add to the knowledge and skills of an engineering undergraduate, they may not be complementing the undergraduate program in order to fill student outcomes not met in the classroom.

Survey of experiences

During the fall semester, surveys were administered to students who had participated in externships over the previous summer. Two programs administered the survey through an online survey program while the other two had participants fill out a word document, though all surveys asked the same questions. Response rate was close to 70% overall with 99 students completing the survey, though in certain demographics the sample size was too small to ascertain discernible trends. The survey consisted of 31 questions with the majority utilizing the Likert scale and the final question being an open-ended question for respondents to add additional thoughts of value from their experience.

Two questions were used to categorize the experiences, a difficult endeavor with such a wide array of experiences. For this reason the questions allowed for some flexibility. The first question asked the students to select two of seven possible categories that describe their externship. The second question asked which engineering topics applied to their experience. The engineering topics differed for different programs (e.g., thermodynamics was an option for mechanical engineering students while analog electronics was an option for electrical engineering students) which made trends across programs difficult to see. Still, the data were useful for each program to see what topics where being applied at their externships so they would know what prerequisites would benefit future candidates.

Since student participants came from various stages in their progression through their engineering program, their level of accomplishment of ABET Student Outcomes would understandably be different, regardless of their type of externship. For this reason we chose to ask students to what degree they were challenged in the areas of the Student Outcomes with the assumption being that the more they were challenged, the more opportunity they had to learn. For these questions a five corresponded to very strongly, a four to strongly, a three to average, a two to weakly, and a one to not at all. A modified version of the ABET Student Outcomes was utilized with a-k appearing to the respondents as:

a. Use math and/or science to solve engineering problems.
b. Design or conduct a scientific experiment to include analyzing or interpreting data.
c. Take part in the design or construction of a system that had real world applications.
d. Operate on teams with engineers/scientists from fields other than (mechanical/aerospace) engineering.
e. Identified, formulated, or solved engineering problems.
f. Made decisions that had social, political, or ethical implications.
g. Have an opportunity to present material related to the externship, either written or orally.
h. See how the project you worked on could have effects on the world beyond engineering, such as economic, environmental, and social impacts.
i. Identify engineering fields that you want to continue further research into.
j. Learn about contemporary issues affecting the scientific or engineering communities.
k. Used techniques, skills, and modern engineering tools necessary for engineering practice.

A statistical analysis was conducted on the survey data to determine trends and patterns. A comparative analysis was also performed on the responses to questions to look for correlation between responses. In particular, the data was compared based on:

- Whether or not a clear goal was provided for the student at the beginning of the externship.
- Whether or not the externship was tied to a project the student was working on either the year prior or projected to be working on the year following.
- The type of externship that the student participated in (technical, acquisition-focused, data analysis, experimentation-focused, project management, design-focused, or experiential/orientation)

The first and third criteria provided interesting results and were the focus of further analysis. Analysis was focused on what preparation led to successful experiences in each category of externships and how those categories of externships complement engineering undergraduate education.

Results

One of the key findings of the survey was the importance of having a clear goal for your externship. For those that agreed with the statement that they received a clear goal for their externship at the beginning, there was a clear increase in degree to which respondents felt they accomplished the goal of their program in the time allotted. This is not very shocking as it is intuitive that one is more likely to accomplish a well-understood mission. However the improvement in experience extends to their responses on how challenged they felt at accomplishing ABET student outcomes with most having a statistically medium to large positive effect on each outcome and all outcomes having an increased average. In Figure 1, the student outcomes that were affected by having a clear goal are displayed with "See how the project they worked on could have effects on the world beyond engineering, such as economic, environmental, and social impacts" having the largest affect.

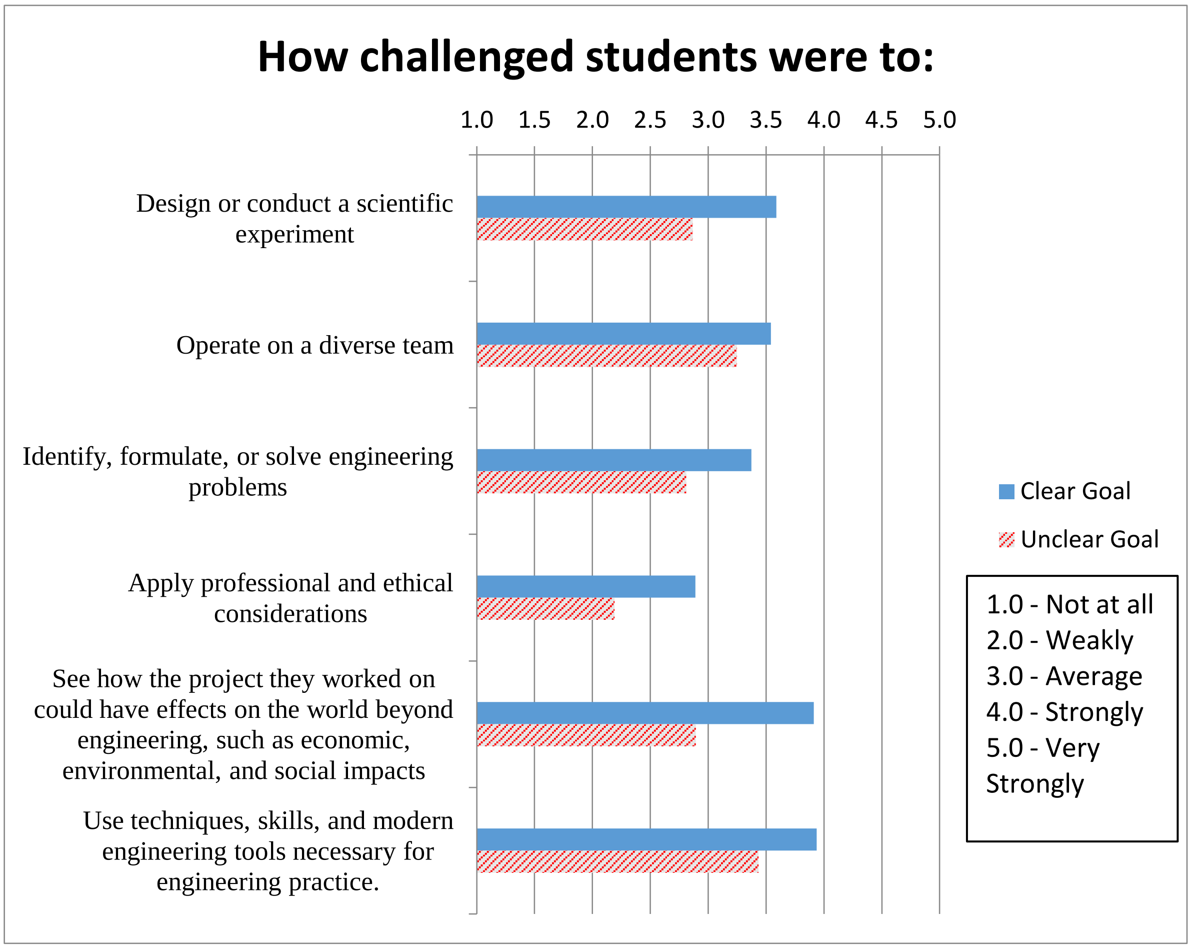

Figure 1

Analyzing the responses by categories, the left chart of Figure 2 shows the worst category of externships at providing a clear goal is Project Management. From the chart on the right, the best category for allowing students to accomplish their goal is Experiential/Orientation. This makes sense as managing projects can be a long, ongoing process making a clear cut goal difficult; and the goal of experiential/orientation externships is to experience what jobs in that field are like, so as long as students are open to experiences they should be able to accomplish this goal.

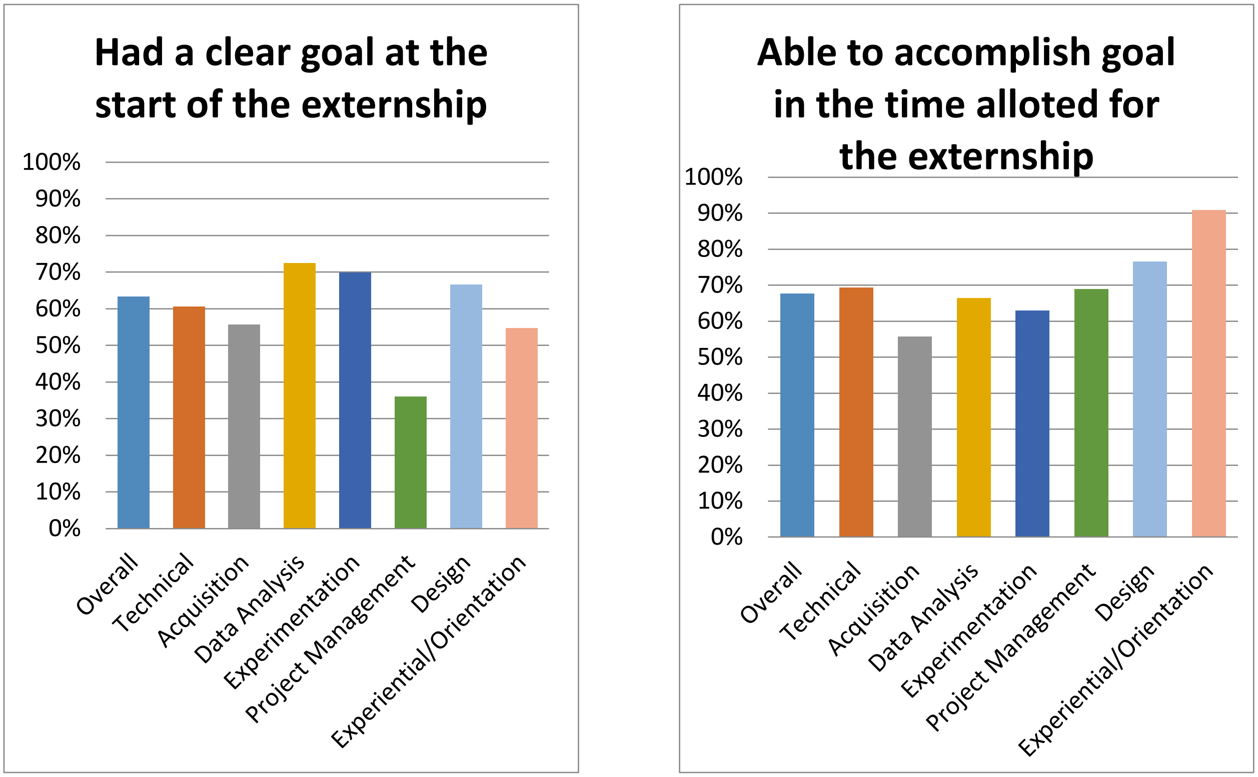

Figure 2

There was an interesting result when comparing the percentage of students who felt they could provide feedback to how strongly they stated that they obtained academic value from the externship. There is a strong positive correlation of 0.836 between these responses which can be visualized in Figure 3.

Looking at the engineering topics applied during externships, all rated computer programming high. Both mechanical engineering programs had strength of materials and mechanics of materials as the next highest. However, only one program had a high number of respondents select the Strength of Materials course as being helpful in preparing for the externship. This difference is likely due to which students had exposure to the course prior to the externship as one program offers it as a sophomore course and the other as a junior course. For other topics, the percentage of externships applying those engineering topics generally lined up with the percentage of externships that utilized courses that taught those engineering topics.

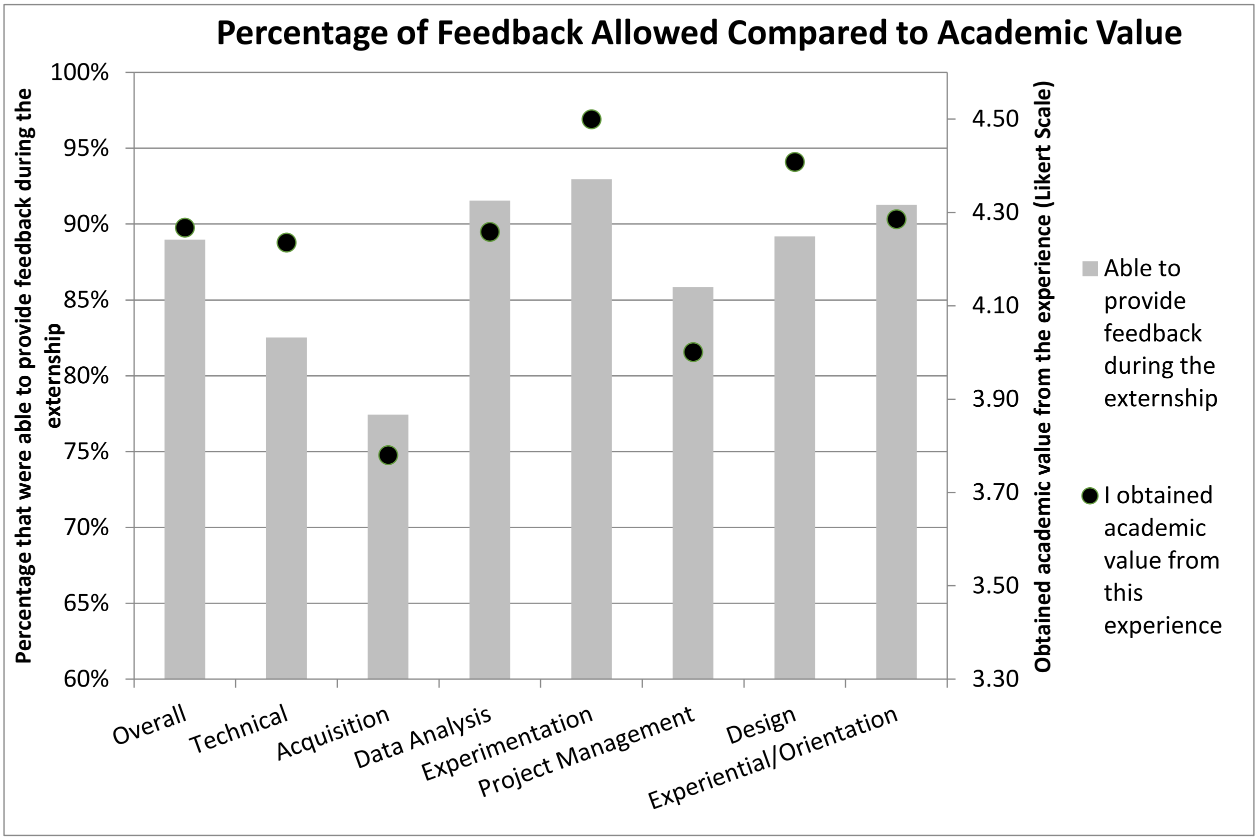

Figure 3

Table 1 lists the degree to which students were challenged to accomplish ABET Student Outcomes broken down by category of externship. Each category has certain Student Outcomes that are more likely to provide opportunities to challenge students. The Student Outcomes that our research group felt each category should perform strongly in are highlighted in the table. The top two values for every Student Outcome are in bold to show which categories provide the best opportunities for students to apply those Outcomes.

Some trends could be seen from engineering topics applied to each category of externship. Experimentation projects tended to utilize more computer programming while design projects utilized more computer aided design knowledge. Additional correlations exist but tend to be program specific (i.e. fluid dynamics is critical for all aerospace engineering externships while simulations is a frequently utilized topic for electrical engineering externships.)

ABET Student Outcomes	**Overall**	**Technical**	**Acquisition**	**Data Analysis**	**Experimentation**	**Project Management**	**Design**	**Experiential/Orientation**
a. Use math and/or science to solve eng. problems	3.30	**3.72**	2.30	3.39	**3.67**	2.65	3.37	3.09
b. Design or conduct a scientific experiment	3.32	3.31	2.93	**3.72**	**4.07**	2.57	2.93	2.73
c. Take part in the design or construction of a system that had real world applications	3.68	3.52	3.45	3.47	3.87	3.43	**4.38**	**4.00**
d. Operate on a multidisciplinary team	3.43	3.33	**3.78**	3.21	3.46	3.71	**4.04**	3.46
e. Identify, formulate, or solve eng. problems	3.16	3.28	3.11	3.19	**3.38**	2.86	**3.41**	3.15
f. Apply professional and ethical considerations	2.63	**2.77**	2.30	2.44	**2.81**	2.57	2.41	**2.77**
g. Communicate effectively	3.42	3.56	3.11	**3.78**	3.42	3.00	3.69	2.94
h. See how the project they worked on could have effects on the world beyond eng.	3.52	**3.56**	2.89	3.53	**3.77**	3.50	3.43	3.43
i. Identify fields to continue further research into	3.96	**4.09**	4.04	3.93	**4.26**	4.00	3.81	4.00
j. Learn about contemporary issues affecting the scientific community	3.61	3.59	**3.78**	3.69	3.54	**3.79**	3.52	3.55
k. Use techniques, skills, and modern eng. tools necessary for eng. practice.	3.75	3.97	3.77	**4.00**	**4.08**	3.50	3.78	3.36

Table 1: Degree to which Students felt challenged to accomplish ABET Student Outcomes (Scale of 1 to 5 with 1 being not at all, 3 being average, and 5 being very strongly)

Improving Externships

The first key takeaway is the importance of providing a clear, obtainable goal for students before they begin an externship. Having a clear goal will significantly increase the learning outcome of students from the experience. Before the student begins the externship, a goal should be submitted by the externship sponsor, acknowledged by the student, and verified by a faculty member. This could be in the form of a contract by which goals and expectations are listed so that everyone understands what is to take place during the externship. By being deliberate with goals and expectations, programs can maximize the likelihood of a positive experience for the student and allow for a sense of accomplishment at the conclusion of the experience.

The correlation of students' ability to provide feedback to a project and their sense of obtaining academic value from the experience deserves further study. It is unclear if the ability to provide feedback meant that students were able to craft their project to what they wanted to learn or if by obtaining feedback students had more questions answered and therefore learned more. There could be no causation at all and it could simply be that externships with strong academic value also have good feedback mechanisms. In the contract specifying goals for the externship, the sponsor and student should identify who the student can expect to get feedback from and how the student should request it. This will alleviate confusion and avoid wasting time during the externship.

Finding the right externship for a student is a balance between what the student is interested in, what the student is capable of doing and what would best complement the students existing curriculum. Based on the survey data, computer aided design and computer programming should be introduced early into a student's course load along with program's introductory engineering course. This will better prepare sophomores for externships who have not had as many engineering courses but may have an opportunity in their upcoming summer to participate in an externship. Mechanical engineering programs should also consider offering mechanics of materials and strength of materials earlier in a student's engineering program as it is frequently applied during externships. Since externships are voluntary they should not completely drive the programming of courses in a department, but they should be a consideration in order to improve the experience of those that do take advantage of them.

Finally, faculty assigning externships to students should consider what Student Outcomes the student needs to develop that his curriculum is not filling at school. If the weakness is constructing systems and working on multidisciplinary teams, a design-focused externship should be considered. If the student does not have a strong grasp of how to apply equations or use modern engineering tools, an experimentation-focused externship should be considered. This is not to say that other categories should not be considered for these students. There were many successful externships in all categories, and regardless of the category type, students were able to find a field that the student would be interested in pursuing further research in. The student's needs are not always the dominant weight in the balancing act with the student's desires and capabilities, however they should be considered.

Conclusion

Externships, though short, can provide excellent learning environments for engineering students and complement their existing study. Due to their short duration it is essential that prior planning be conducted to maximize effectiveness during the externship. Identifying clear and obtainable goals, expectations, and means of providing feedback can increase the success of the experience. Considerations should be made for what ABET Student Outcomes the student is weakest at. It does not have to be the deciding factor for whether or not a student gets assigned an externship, but doing so can lead to a more balanced engineering education. Each externship does not need to challenge students in all Student Outcomes as long as it challenges them in the Outcomes that play to its category's strengths.

For subsequent research into the quality and composition of externships, every effort should be made to have a survey ready for students to fill out as soon as their externship is complete. Our research group did not get together to discuss the composition of the survey until after the start of the fall semester. This led to a month of discussion and refinement before the surveys were sent out to the recipients. Having the surveys ready sooner would likely lead to a higher response rate and would provide students the opportunity to reflect on their experience while it is still fresh in their mind.

Future surveys should also look to remove questions that showed little to no correlation to the success of the externship. Shorter surveys encourage a faster response rate and prevent frustration from students feeling like they have answered the same question in multiple manners. This would also make room for researchers to add other questions to find other correlations to success of the experiences.

Further research should include surveys of the externship sponsors to gain their evaluation of how the students preformed and what learning took place. It was attempted to be performed for this study, but the surveys were sent out too late and elicited such a small response as to provide no useable data. Having the surveys ready at the end of the externship – with a forewarning at the beginning of the experience as to what is being evaluated – would provide valuable insight into the performance of the students and their preparation. Another area to look into would be the effect of whether course credit is offered for the externship. This should definitely improve students' responses to "Communicates effectively" as providing course credit would necessitate a presentation or report at the end of the experience. Finally, a study could look at whether the ability to provide feedback causes a higher sense of academic outcome or is simple a corollary of it.

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