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Leveraging Summer Immersive Experiences into ABET Curricula

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Abstract

Summer immersive experiences for undergraduate students in Aeronautical and Mechanical Engineering programs come in varied forms and can represent a substantial effort by staff and faculty, as well as considerable financial resources to coordinate. Experiences range from work in governmental laboratories and research centers to collaboration with industry partners, and may include graduate research at distant academic locations. This study seeks to evaluate the utility of these work experiences, measuring their effectiveness across ABET program outcomes and assessing their contribution to student learning and motivation to continue to learn. A survey of 53 students who conducted immersive experiences related to Aeronautical and Mechanical Engineering disciplines from the United States Air Force Academy and the United States Military Academy has been conducted. Survey results are analyzed to determine the overall value provided by the experience as measured across program outcomes outlined in ABET criteria 3 (a-k). The unique contributions available from the experience are balanced with the administrative requirements to suggest a best practice in leveraging the most from these experiences and to assist programs that might consider initiating or refining their own participation in similar programs.

Introduction

For decades, the engineering community has wrestled with finding an appropriate balance between classical educational pedagogy and practical research and/or design experiences for developing engineers at the undergraduate level. There is no single recipe for success that all programs should follow, though much has been discussed on the topic and the idea of change and reform is not a new one[1-4]. An example of a major reform activity is the timing of the introduction of engineering design into a program's curriculum. The literature is replete with generally successful examples, a subset of which can be found in the references suggested by Dym et al[5]. Substantial reformative progress on a broad scale has been made since Engineering Criteria 2000 was first introduced as an ABET initiative designed to make step changes in engineering education[6]. It recommends assessment metrics designed to assist programs with continuous improvement. Commonly, Criterion 3 – Program Outcomes and Assessment, is discussed. According to ABET, engineering programs must demonstrate that their graduates have:

(a) ability to apply knowledge of mathematics, science, and engineering,
(b) ability to design and conduct experiments, as well as to analyze and interpret data,
(c) ability to design a system, component, or process to meet desired needs,
(d) ability to function on multi-disciplinary teams,
(e) ability to identify, formulate, and solve engineering problems,
(f) understanding of professional and ethical responsibility,
(g) ability to communicate effectively,
(h) broad education necessary to understand the impact of engineering solutions in a global and societal context,
(i) recognition of the need for, and an ability to engage in life-long learning,
(j) knowledge of contemporary issues,

(k) ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Largely due to the ABET initiatives, capstone or design courses emerged as one response to an increasingly positive view of incorporating project-oriented work into undergraduate engineering programs. Kolb's work is often cited regarding experiential learning as the start of discussions regarding active experimentation[7]. Along with others, Siddique et. al. map educational objectives and learning environment to projects in their assessment of a particular capstone experience[8], with a positive assessment for their articulated outcomes. Generally, the literature is supportive of capstone experiences[3, 8-15], and since these senior projects can sometimes span multiple years, extensive administrative and faculty support is often required. In some cases, new organizations or project centers within departments or engineering schools are formed to handle the administrative/support requirements, such as in Floersheim et. al.[16]. This may be especially true as the projects mature into interdisciplinary efforts with diverse sponsors/clients, funding streams and student/faculty participation across departments/colleges.

The general idea of undergraduate research is more hotly debated than that of capstone or senior design projects[17-21], but it appears to be gaining in support across a broad contingent of universities. The Massachusetts Institute of Technology developed the first institution-wide undergraduate research program in 1969, with many other institutions following suit in the subsequent decades[3, 22]. Assessments, such as the one done at the University of Delaware[22, 23], increasingly include program graduates, though limitations in sample size and diversity in population and control groups challenge any such undertaking. Of note in[22], the highest rated research-type experience by alumni was the summer internship, which exceeded individual research, honors classes, employment, and studies abroad. The summer internship experience is varied in application. At Purdue[24], it functions as a cooperative degree program with three separate 12-week experiences, but for most realizations, it is a single summer, usually late in the undergraduate experience. While summer internship opportunities occur with industry partner support, there is little literature available that assesses diverse internship opportunities across a range of categories.

In light of the background discussion above, the objective of this introductory effort is two-fold. First, we provide a broad overview of the results of the program with regard to ABET outcomes. Second, we recommend potential best practices for internships of each type within the context of the two institutional types that generated the data, with implementation and assessment of these best practices planned as a future activity.

Summer Internship Opportunities

The summer internship opportunity, as defined within the context of this work, is an optional, practical engineering experience afforded to students at the United States Military Academy (USMA, West Point, NY) and the United States Air Force Academy (USAFA, Colorado Springs, CO) during the summer with no academic credit generally awarded. Each of the programs surveyed are semester-based, with an available summer time window for students lasting approximately 11 weeks. In addition to academic opportunities, there are competing demands for student time including mandatory military and/or physical development programs. Not all students have sufficient time to enroll in a summer academic internship, although some form of summer developmental program is included as a graduation requirement from each of the institutions participating in this study. These opportunities have different lengths, with 42% lasting 17-21 days for the included study, 13% 22-28 days, and the remainder 29-44 days in duration.

In most cases, the students are allowed to request specific opportunities based on appropriate backgrounds and utilizing a single page project description that is provided. The description includes a project title, description, geographic information, project point of contact details, academic requirements, and preferred time windows if applicable. Some students will be pre-selected to attend specific internships that are aligned with academic year research or capstone design projects with which those students are engaged. Further, the summer internship program is generally available to students who have declared their academic major, an event that usually happens during the 2nd undergraduate year. Figure 1 illustrates the numbers of years of schooling completed by each participant prior to attending their internship. The majority of the students attended their internship after completing three years of academic study. Approximately 2/3 of the survey participants were enrolled in the USMA Mechanical Engineering program, the remainder were enrolled in the USAFA Aerospace Engineering program.

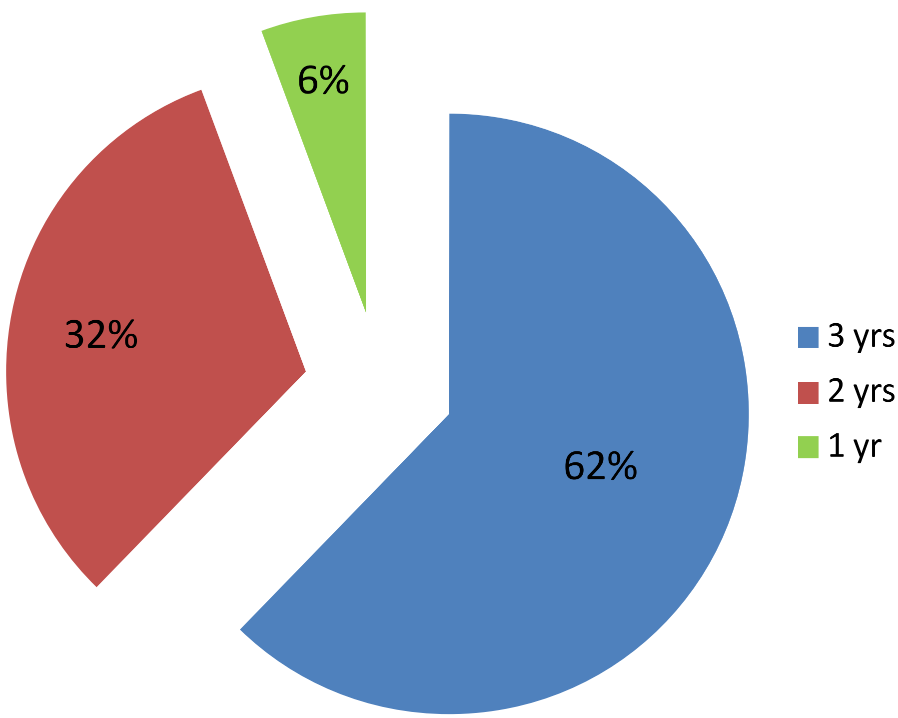

Figure 1. Student intern population as represented by the number of years of study completed at their home institution prior to attending a summer internship.

Project opportunities vary widely across the two institutions. The majority of projects are accepted with agreement by the host agency to provide all local support and any required travel funding. Students travelled away from the home academic institution to governmental laboratories and research facilities, partnered with corporate and industry sponsors, and also joined research groups at universities with graduate programs. Typically the students conduct the internships alone or in very small groups with peers; periodically faculty members will accompany them or check-in on them during the summer. Table 1 provides a summary of some of the representative summer internship locations. Approximately 66% of students worked at a governmental lab or agency, 23% worked with industry sponsors, and 11% worked at academic institutions. Student responsibilities varied with the projects. In some cases, students analyzed existing data and provided summaries or conducted computational analyses of problems. In other cases, students designed and conducted experiments using existing facilities. A few projects involved identifying and solving problems on existing systems. In addition to taking the survey, most students provided an end of project summary briefing to the project sponsor and assessed the project in written form to the program facilitators from the home academic institutions.

Table 1. Summary of Major Project Opportunities by Category (not complete)

Governmental Laboratories	Industry-Sponsored	Academia
Army Research Laboratory (ARL)	Raytheon Corporation	Naval Postgraduate School (NPS)
Air Force Research Laboratory (AFRL)	Alliant Tech System (ATK)	Stanford University
Tank and Automotive Research and Development and Engineering Center (TARDEC)	L3 Communications	University of Maryland
Aviation and Missile Research and Development and Engineering Center (AMRDEC)	Sikorsky Aircraft	University of Cambridge, UK
Air Force Operational Test and Evaluation Center (AFOTEC)	Spring Active Inc.	
Arnold Engineering Development Center (AEDC)	United Color Corporation	
NASA	Rolls-Royce	
Lincoln Laboratory at M.I.T.	Lockheed-Martin	
Naval Surface Warfare Center	Boeing	
Soldier Research Development and Engineering Center (SRDEC)	GENTEX	

Survey Methodology

The survey was an adaptation of one designed and developed for the assessment of the goals and objectives of one of the institutions. The original items were developed by a team giving consideration to their institution's specific academic goals. This survey was pilot tested with a select group of students interning in the Washington DC area. Based on student responses and comments, the survey was adjusted for clarity and specificity; it was administered in the early fall upon the arrival of students for the new semester.

The items used in this survey were adjusted from the original survey by considering the ABET Criteria 3 (a-k) outcomes. Pilot testing was not possible as there were too few students to allow for such separate testing. However, engineering faculty, as content area experts, as well as an educational psychologist, as a survey expert, verified the new survey's content validity. As will be demonstrated below, the results provide evidence that the 28 survey items were understood by students, were responded to honestly, were able to distinguish students from one another, and overall met the team's objectives.

Results and Discussion

There were 28 survey questions utilized in this assessment. The Academic Individual Advanced Development (AIAD) is the name attributed to the summer internship opportunity throughout the survey and this discussion. The first category of questions identified demographic characteristics such as level of schooling, coordination, project duration, and whether the internship was directly linked to an existing or anticipated project. Table 2 lists the questions within this category.

Table 2. Questions in Survey 'Demographic Category'

Question	Question
1. What was the length of your AIAD/Summer Internship Program?	5. I was given a clearly defined goal for my AIAD either before arriving there or upon arrival.
2. What level of schooling had you completed prior to attending your AIAD?	6. I was able to accomplish the goal of my AIAD in the amount of time provided.
3. I received coordination with my AIAD organization prior to the start of my AIAD.	7. I was able to provide feedback into the project.
4. My AIAD organization was prepared to accept me and put me to work.	8. To what extent was your AIAD work linked to a project in the prior school year or projected to be pursued in the current school year?

The opportunity to contact the sponsoring organization for initial project discussions was afforded to students in advance of the summer internship. Advanced coordination is required by the staff and/or faculty program manager prior to sending students to a project sponsor to define the project scope, support requirements and deliverables. Figure 2 shows the means of responses from the students who completed the survey (ratings of 1-5 with 5 representing *strongly agree* and 1 representing *strongly disagree*). The first category of questions is associated with on-boarding processes and attainment of project goals.

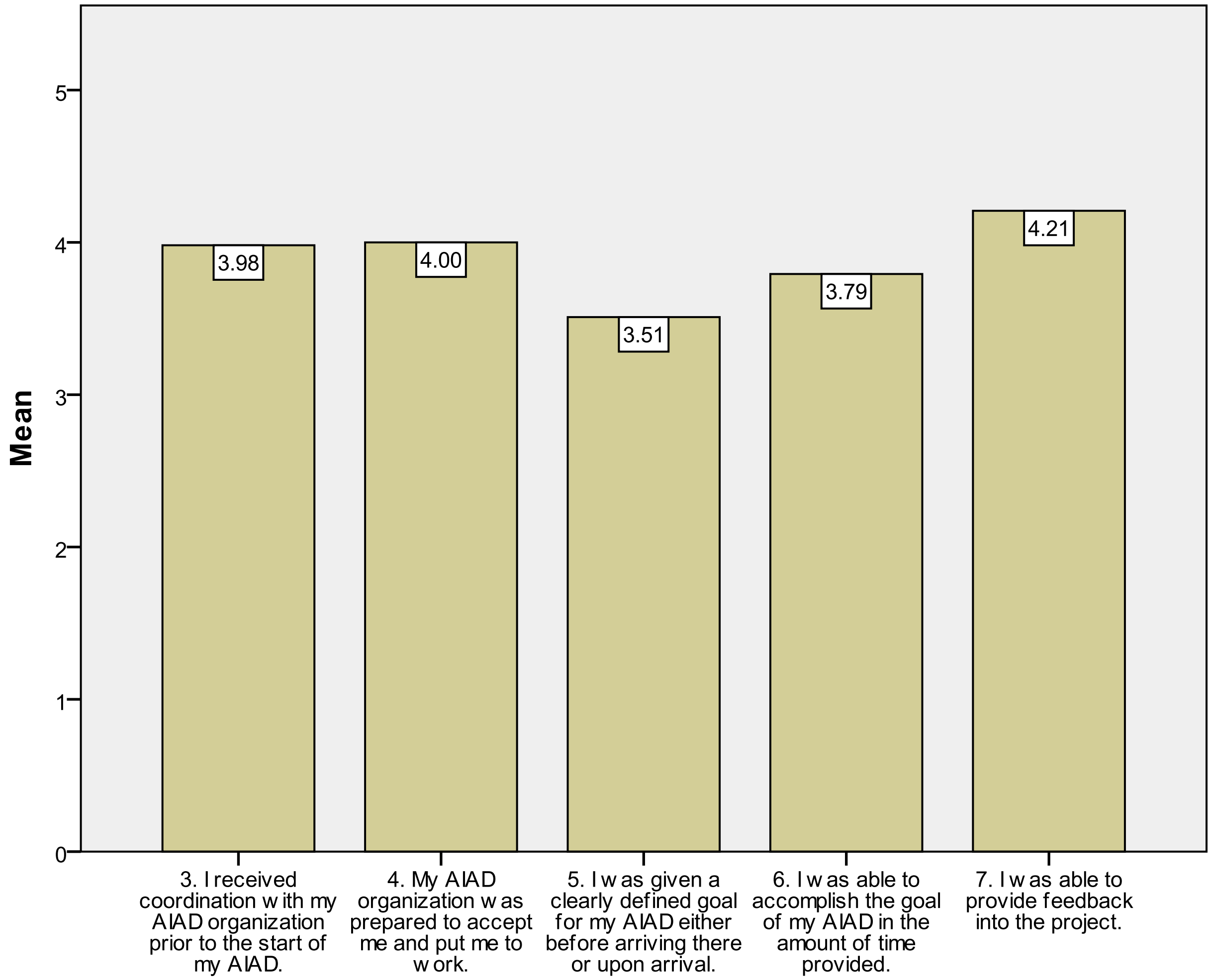

Figure 2. Response means for survey questions linked to project on-boarding and goal attainment

Figure 3 illustrates that for the population surveyed, a small minority had existing or future project linkages, nominally because the administration of the AIAD program is conducted independently from the senior Capstone Design/Capstone Project selection at each institution. However, a larger percentage of students pursuing independent research study will have a project that carries over from summer to academic year. At a minimum, an indirect linkage is expected, as senior projects and summer internships have a common theme of supporting either the Aeronautical or Mechanical Engineering programs at the institutions.

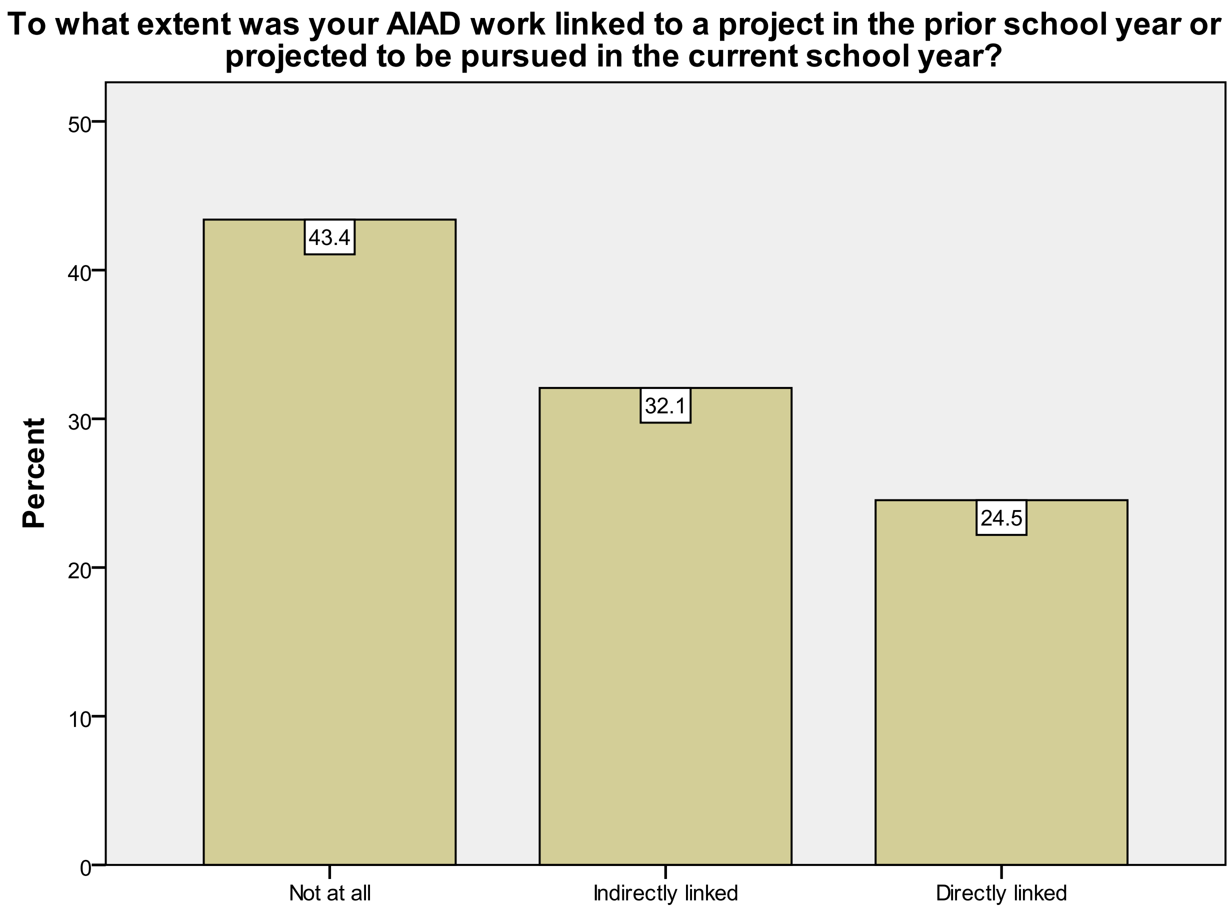

Figure 3. Project linkage (Question 8)

The next category of questions investigates the perceived preparation level of the students who travelled. Table 3 lists the questions from this category along with a statistical summary of the mean and standard deviation of each item using the same 5-point Likert scale as before. It is worth noting the fairly large standard deviations associated with the latter 2 questions regarding suitability of particular projects for continued study. In general, however, Mechanical Engineering and Aeronautical Systems majors felt like they were adequately prepared or the project was appropriately crafted to their skill levels, as indicated by the relatively high mean value for questions 11 and 12.

Table 3. Questions related to the preparation level of students conducting internships.

Question	Mean	SD
11. My experiences in the Mechanical/Aero Engineering program prepared me for my AIAD/internship experience.	4.11	0.85
12. My AIAD reinforced concepts, theories, or principles learned previously in my Mechanical Engineering program.	4.13	0.86
13. The research/project I started during my AIAD could be continued and completed in one academic year as an Individual Study or Capstone Project.	3.26	1.27
14. The research/project I started during my AIAD would be appropriate as a Mechanical Engineering Individual Study or Capstone Project.	3.35	1.25

The final category of questions relates to the ABET Program Outcomes addressed previously. In Table 4, several of the outcomes have been de-composed in such a way as to reduce multi-factor confounding and allow for a Likert scale rating of distinct metrics. In three cases, two questions were utilized for a single program outcome, as in questions 16-17 (outcome b), 21-22 (outcome f), and 27-28 (outcome k). In two of these cases there is a significant difference in the average response based on the isolated metrics in question, such as with questions 16 and 17 which have well over a half point separating them. Broadly, the summer internship experiences received positive ratings amongst students from the context of these program outcomes. As summer internships provide a unique opportunity within the program to diversify the academic experience, they are perhaps uniquely suited to address specific program outcomes, as suggested by the relatively higher mean values in questions 17, 27 and 28.

Table 4. Questions directly related to ABET Program Outcomes.

Question	Mean	SD
15. Use math and/or science to solve engineering problems?	3.58	1.19
16. Design or conduct a scientific experiment?	3.22	1.38
17. Analyze or interpret data?	3.98	1.22
18. Take part in the design or construction of a system that had real world applications?	3.79	1.25
19. Operate on a multidisciplinary team?	3.51	1.19
20. Identify, formulate, or solve engineering problems?	3.42	1.35
21. Encounter situations in which professional responsibility was displayed (e.g., Engineers showing accountability for actions)?	3.81	1.11
22. Encounter situations in which ethical implications of actions or decisions were taken into consideration?	3.45	1.18
23. Have an opportunity to present material related to the AIAD, either written or orally?	3.58	1.12
24. See how the project you worked on could have effects on the world beyond engineering, such as economic, environmental, and social impacts?	3.50	1.16
25. Identify engineering fields that you want to continue further research into?	3.74	1.11
26. Learn about contemporary issues affecting the scientific or engineering communities?	3.43	1.10
27. Use engineering tools and/or techniques to accomplish the goal of your AIAD?	4.13	0.97
28. Use engineering software to accomplish the goal of your AIAD?	3.92	1.37

Several factors were investigated further to determine whether specific groups answered questions differently than others. First, the results are separated by the category of project – governmental lab, industry, or academic and compared to assess trends. As not all questions are distinguishable using this categorization, the results are provided primarily for the questions related to the ABET Program Outcomes. Figure 4 depicts the complete list of responses to these questions by the appropriate project category.

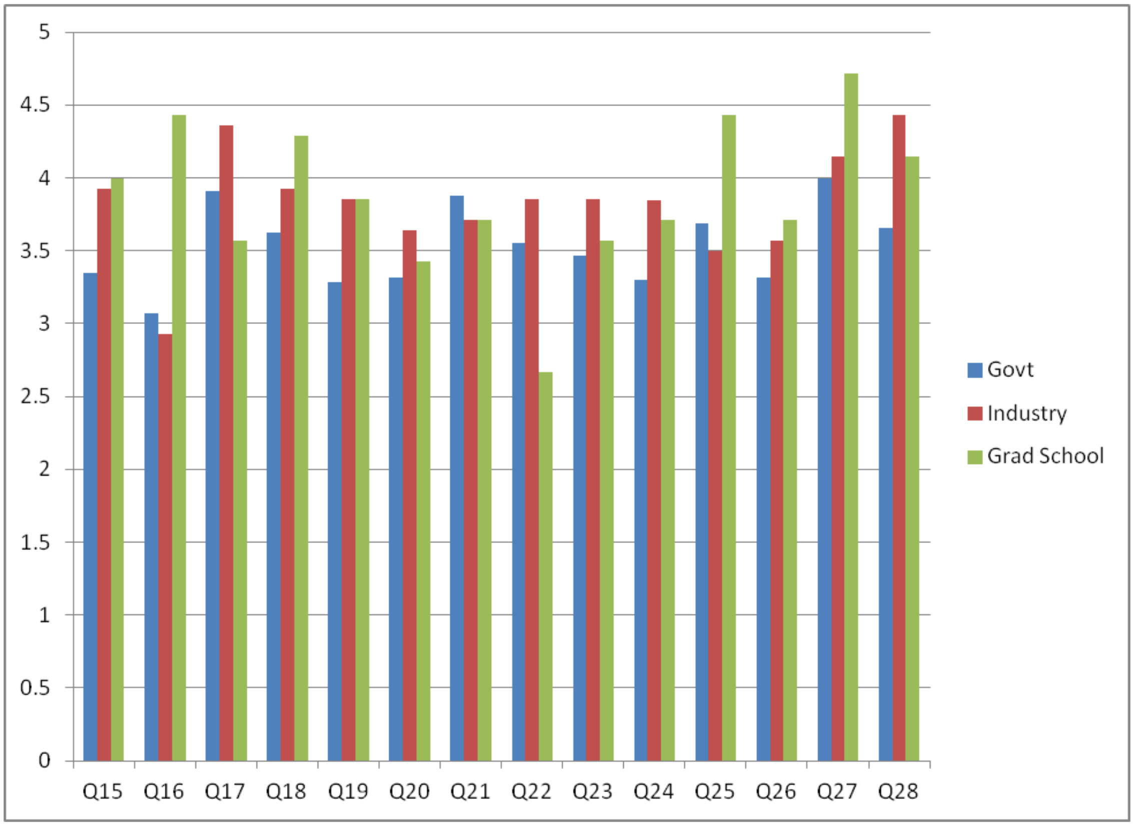

Figure 4. Responses to Questions 15-28 based on project category.

Figure 4 has several notable features. Graduate school experiences were more favorably disposed towards design and implementation of an experiment with real world applications. In addition, graduate school experiences highly rated the identification of future engineering fields to pursue, and engineering tools are well used in the graduate school experience, as expected. Industry-sponsored projects had comparatively strong responses to data analysis and interpretation, and the ethical implications of the work. The use of engineering software was also strongest on average for industry-sponsored projects. Projects associated with governmental laboratories and research facilities, the most common project type of the three, held a slight edge in terms of the question relating to professional responsibility. While no single project category excelled in all areas, clearly the project category selected for a summer internship experience can have on average a more favorable influence on specific program outcomes than others. For example, Figure 4 shows that an industry-sponsored project rates highest across 50% of the program outcomes, compared to 43% for graduate school projects and only 7% for experiences at governmental laboratories.

A variety of additional trends were gauged to see if they had any significant effects on groups of questions. For example, project duration, which was separated into projects less than 21 days and projects more than 21 days, showed a significant deviation in terms of how Question 28 (use of engineering software) was answered. The students who went on shorter duration projects, which were 25 of the 53 respondents, had an average of 3.32 for this question, whereas students who went on longer internships had an average of 4.46. Other questions that depicted significant differences based on project duration showed a preference for the shorter projects. This included the opportunity to work as a multi-disciplinary team. Those who had shorter projects were more likely to conduct inter-disciplinary team work than those on longer projects by an average difference of 0.70 points (3.88 compared to 3.18 for longer duration projects). In addition, those on shorter projects rated their understanding of the projects effects on the world beyond engineering (Question 24) higher by an average of 0.65 (3.86 compared to 3.21). Duration of the experience did not correlate with outcome responses in a consistent enough fashion to establish any general trends based simply upon the length of the program. It is possible that since all of these projects are six weeks or less, and since there are only two distinct categories of duration to utilize for comparison, there may simply be insufficient differentiation to extract any general trends or further correlation of responses related to the project duration. A surprising result was noted when comparing the level of preparation students felt (Question 5) when arriving at their internship location. For those students who did not feel like they had a clearly defined goal upon arriving, they felt forced to identify/solve engineering problems with an average response of 4.0, compared to 3.25 for their counterparts who were given a clearer objective.

Students who had completed three years of undergraduate education were far more likely to use engineering software (Question 28) than those less experienced in the program by a substantive margin of 1.05 (4.40 compared to 3.35 for the under classes). For the minority of students who saw a linkage between their project and a previous/future project at their school (Question 8), they were less likely to design or conduct a scientific effort, perhaps because the project was too new or mature for initial experimental testing. This trait is not necessarily negative – the experimental component in several cases was conducted at the home institution. In addition, those with direct linkages between summer internship and academic projects had a stronger connection to professional responsibility (Question 21) than their counterparts with a mean score of 4.15 compared to 3.70 for those who saw no linkage to existing or future projects. It is surprising for both programs that there is not a wider array of positive outcomes for projects that have this linkage. Pedagogically, it is assumed that continuity would be a favorable characteristic in terms of program outcomes, but the data to date does not support this conclusion.

The grade point average (GPA) within the major was used to see whether high academic performance correlated with any of the responses on specific questions in the survey. Two questions, 24 and 26, showed a relatively high degree of positive correlation between respondent GPA and response agreement indicating that external effects and contemporary issues were more clearly visible to those with higher classroom performance. However, since most of the respondents from each institution had relatively high GPA's (nearly everyone had a 3.0 or higher, with a mean GPA of 3.56 for the interns), there was little other differentiation based on this index of performance.

The data were also analyzed with respect to each institution to determine if any significant differences exist in responses. The average GPAs for the two programs were similar (3.65 for the Mechanical Engineering students and 3.41 for the Aeronautical Engineering students) indicating that the quality of the two student populations was comparable. Additionally, each program had roughly the same percentage of students attend the three different types of internships -- governmental organization, graduate school, or industry partner -- indicating a level of similarity between the types of opportunities available. The average Aeronautical Engineering internship lasted 28 days while the average Mechanical Engineering internship lasted 23 days. Table 5 compares the average response to selected questions for the two programs.

Table 5. Comparison of Mean Responses of Mechanical and Aeronautical Engineering Programs

Survey Question	Mech Eng Program	Aero Eng Program
5. I was given a clearly defined goal for my AIAD either before arriving there or upon arrival.	3.74	3.11
16. Design or conduct a scientific experiment?	3.63	2.53
19. Operate on a multidisciplinary team?	3.74	3.11
20. Identify, formulate, or solve engineering problems?	3.24	3.74
23. Have an opportunity to present material related to the AIAD, either written or orally?	3.41	3.89
28. Use engineering software to accomplish the goal of your AIAD?	3.53	4.63

The differences seen in goals definition and presentation of material (Questions 5 and 23, respectively) are likely due to differences in program requirements and administration. For instance, the USAFA Aeronautical Engineering students were required to present a briefing for senior leadership at their internship location and write a report of the work when they returned to their home institution. In question 16, the Mechanical Engineering students (USMA) reported that they were significantly more involved (+1.10) in designing or conducting a scientific experiment. The low response by the Aeronautical Engineering students is related to an emphasis on data analysis and computational studies as opposed to physical lab experiments. Interestingly, the results in question 16 are contrasted with the response to question 20 that showed that the Aeronautical Engineering students were more involved (+0.50) with identifying, formulating and solving engineering problems. These differences are likely to be attributed to the types of projects that the students are assigned to which is in turn influenced by the length of the internships. The large difference (+1.10) in question 28 is also attributed to the length of the internships and it appears as though longer internships lead to students becoming more deeply involved in analysis and problem solving. Question 19 favors the Mechanical Engineering internships (+0.63) and this is possibly related to the inherent multidisciplinary nature of the Mechanical Engineering discipline.

Best Practices

The suggestion of best practices from the results of this analysis is a challenging task. Since every project is different in terms of the student who arrives as well as the potential nature, location, and duration of the work to be accomplished, there is no recipe for individual success apart from broad principles. In addition, the results of the survey utilized in this study do not conclusively point to an optimum combination of internship project type, location, duration, that would be expected to yield demonstrably improved response results for the program outcomes. However, from a broad program perspective, there are thematic elements of successful implementation of summer internship opportunities from the perspective of the impact on the overall program outcomes, based on the perception that the summer internship opportunities as administered by these two institutions are generally successful. These principles are briefly summarized in this section.

A diverse set of project opportunities sets conditions for student selection that can incorporate many factors, including geography, project outcome, focus area, and institution. Although not surveyed directly, students indicate anecdotally that geographic location is a key ingredient to student satisfaction, which can directly impact their perception of the project and experience. Historically, the most subscribed project opportunities within the program are usually set in locations that appeal to a typical college student (ie. near a warm beach with a youthful community and a vibrant night-life). In addition, students seeking competitive scholarship-related activities such as those offered through the National Science Foundation, Hertz Foundation, Winston Churchill Foundation, and others, aspire to work that could culminate in a technical publication or conference presentation. Still other students gravitate to projects based on sub-discipline or focus area within the major. Within the Mechanical Engineering program at the USMA, bio-mechanical summer internships, often at various medical facilities, are sought as the departmental coursework within this sub-discipline tends to be quite broad, whereas the project opportunities are usually quite focused with additional opportunities to observe medical practice in a clinical setting. Finally, students tend to gravitate toward reputable (well-known) industry sponsors, top tier academic institutions, and/or nationally-recognized research laboratories with which to spend their discretionary internship time. Our strategy is to offer a wide range of projects that will appeal to a broad spectrum of preferences.

Assuming there are multiple project opportunities and that students are allowed to have some say in selection of their assignments, the utilization of appropriate selection criteria is important. Faculty involvement is another important aspect. If the administration of the summer internship program is done by non-teaching members of the faculty or by a single faculty member with a very large load of student assignments to coordinate, the likelihood that an assignment will be best tailored to an individual is reduced. Faculty members who are involved with selection and preparation of the students with knowledge about the specifics of the project for which they are selecting will select more qualified students than if this is not practiced. The natural limitations regarding faculty availability and time investment will always make this difficult to achieve in practice. Finally, the student must make themselves available for an appropriate duration for the specific project. A minimum of three weeks of actual project time excluding holidays is suggested for any project designed to achieve ABET program outcomes.

Conclusions

While this initial attempt to quantify the results of summer engineering internships as executed at the United States Military Academy and the United States Air Force Academy did not yield any startling insights that would cause us to change current practices, it does provide a baseline of information and set the stage for a continued longer-term look at the success of these programs. Primarily, the sole use of the student survey limits the assessment data set; future work should include adopting and testing complementary assessment devices. It is clear that while the activities may not be located on an academic campus, the linkage to the academic program outcomes demands that educators stay involved through the process.

A successful summer internship program may contribute in a meaningful fashion to achievement of program outcomes. A thorough review and assessment process must be incorporated to ensure that projects are meeting the requirements of the program effectively. Projects where students are not able to achieve the desired program outcomes must be discontinued to sustain success. Use of internship outbriefs to program faculty, and generation of post-project reviews facilitate the data collection for analysis. This activity will also naturally serve as a strong advertisement for the success of the partnership between project hosts and the institutions providing the student.

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