International Journal of Computer and Systems Engineering

Volume 2 | Issue 1 Article 3

June 2021

ABET Assessment And The Capstone, Part 2: Realistic Constraints

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International Journal of Computer and Systems Engineering
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ABET Assessment And The Capstone, Part 2: Realistic Constraints

Outcome assessment tactics for ABET

by Douglas Lyon, Ph.D.

Abstract

This paper presents the second part of a multi-part framework that enables ABET accredited engineering programs to establish and maintain their compliance with the general criteria for standards, realistic constraints and a major design experience. Each of these elements are covered separate parts, in this, Part 2, we cover *realistic constraints*. We have found that some schools use interdisciplinary-teams in their senior projects. When the outcomes from interdisciplinary teams are co-mingled it triggers ABET issues as the outcomes are not program specific. Moreover, some schools use the senior project (i.e., capstone) as their only means of providing evidence of a major design experience, student understanding of standards and the application of realistic constraints. This creates ABET issues as program evaluators require assessments to be program-oriented.

1. Problem Statement

ABET (formally known as the Accreditation Board for Engineering and Technology) makes use of a curriculum criterion known as *Criterion 5*. The curriculum criterion requires that programs provide evidence of “a culminating major engineering design experience that 1) incorporates appropriate engineering standards and multiple constraints, and 2) is based on the knowledge and skills acquired in earlier course work.”

How do we know when we are compliant with the “major engineering design experience” with “appropriate engineering standards and multiple constraints” criterion? Where should the standards and constraints outcomes be measured? How can we have program-oriented measurement of these things when we have interdisciplinary teams? Direct examination of student work is only effective on a teambasis when the team is from the same program. Thus interdisciplinary teams confound program-oriented evaluation and yet provide intrinsic value that programs have embraced.

We are motivated to study this problem because, in the 2020-2021 period 979 ABET Experts, evaluated 758 programs at 188 institutions in 17 countries, resulting in an increase of 54 accredited programs over last year. As a result, we now have a total of 4,361 programs accredited at 850 institutions in 41 countries. More than 970 of these are located outside of the U.S., accounting for over 20 percent of all ABET-accredited programs

2. Approach

The term "culminating major engineering design experience" is often interpreted to mean a senior project or a capstone experience. While standards and realistic constraints may be introduced in earlier courses, if they do not result in a "major engineering design experience" and so the student outcomes will not be criterion compliant as is done in [Wear et Al.]. For example, a fundamentals of engineering course taken by our freshman does address standards and realistic constraints, however, it does not have a culminating engineering design experience and thus the coverage lacks criterion compliance. Thus, we devise assessment instruments that focus on senior project outcomes, as this is the "culminating major engineering design experience". Our assessment includes automated summative and manual formative assessment. Formative feedback obtained from manual assessment of essays written by individual students is grouped by program. We do not assess interdisciplinary teams when providing evidence of compliance because this would result in comingled data. Thus, we use program-oriented assessment of student work to obtain evidence of compliance with curriculum criterion. In comparison [James-Okeke et Al.] uses a more integrative approach across multiple courses. Our approach is more like [McCullough] except that their approach assumes homogenous teams, while our teams are interdisciplinary.

3. Summative Assessment of Realistic Constraints

This section describes the automated summative assessment instrument used for measuring student understanding of realistic constraints. These are designed to obtain student-specific outcomes for later organization by program and is implements in *Blackboard*, our course management system.

1. (True/False) You can have social constraints
2. (True/False) Designs can favor some kinds of people but not others
3. (True/False) Designs favor employers
4. (True/False) Designs are developed with public funding
5. (True/False) Some designs pose negative side effects for a specific race or gender
6. (True/False) Some designs infringe on existing patents or copyrights
7. (True/False) Some designs are not safe for children
8. (True/False) Price is a realistic constraint.
9. (True/False) Potential impact to the local economy is a realistic constraint
10. (True/False) Potential impact to the US economy is a realistic constraint
11. (True/False) Over designs and under designs cost money
12. (True/False) Environmental considerations can be realistic constraints
13. (True/False) Vibration induced noise can impact workers
14. (True/False) Vibration can impact product users
15. (True/False) High maintenance cost is not a realistic constraint
16. (True/False) Road lamps can cause noise in the public
17. (True/False) Large power transformers can cause noise in the public

18. (True/False) Making things out of plastic and other non-biodegradable materials is a realistic constraint that cannot be avoided
19. (Multiple Answer) Attributes for realistic design include:
    (Answers)
    - Space debris
    - Energy saving
    - Global warming
    - Control of exhaust temperature
    - All of the above
20. (Multiple Choice) Engineering designs can result in:
    (Answers)
    - Budget issues
    - Profit issues
    - Maintenance issues
    - All of the above
21. (True/False) Engine friction considerations often constrain the type of oil we are permitted to use
22. (Multiple Choice) The general requirements and limitations that are incorporated into the design of a structure are known as:
    (Answers)
    - Creativity and innovation
    - Form and Function
    - Criteria and constraints
    - Marketability and safety
23. (Multiple Choice) The criteria and constraints of a product or system, and the determining factors on how they affect the final design and development, are called:
    (Answers)
    - Requirements
    - Recommendations
    - Resources
    - Risks
24. (Multiple Choice) If a product does not meet the established criteria during production, issues related to its:
    (Answers)
    - Designs must be investigated.
    - Quality control must be investigated.
    - Ergonomics must be investigated.
    - Regulations must be investigated
25. (Multiple Choice) The purpose of a case study when conducting problem-solving research is to:
    (Answers)
    - Select an appropriate solution to a problem
    - Make sure the designer has not stolen other's solutions or ideas.
    - Document where and how others have made mistakes in solving a problem.
    - Assess the current understanding of a problem

A single figure, per program, can be used to summarize the assessment of the student outcomes;

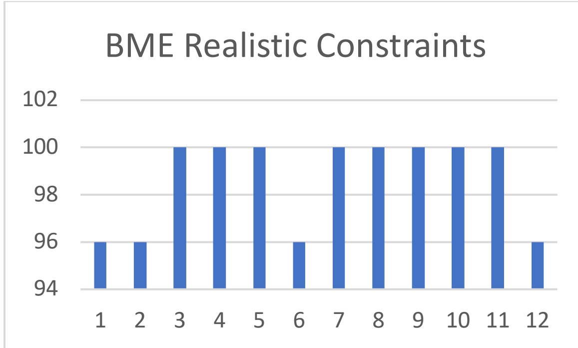

Figure 3-1. BME Realistic Constraints

Figure 3-1 shows a summary of the assessment of student work in the area of realistic constraints for the biomedical engineering program.

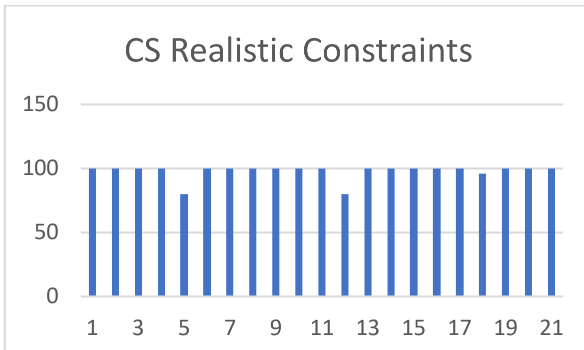

Figure 3-2. CS Realistic Constraints

Figure 3-2 shows a summary of realistic constraints for the computer science program.

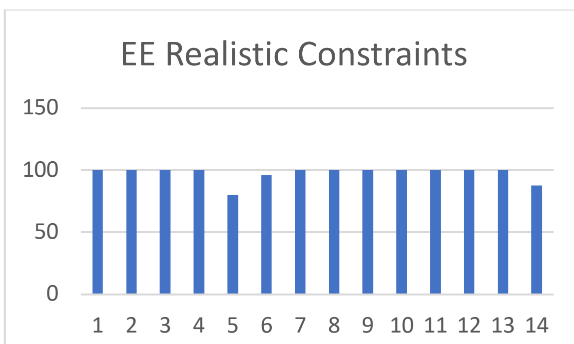

Figure 3-3. EE Realistic Constraints

Figure 3-3 shows the realistic constraints summary for the electrical engineering program.

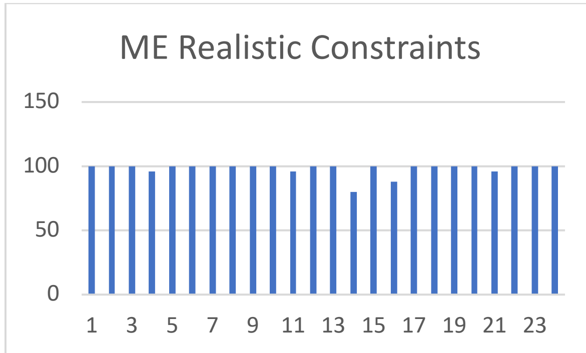

Figure 3-4. ME Realistic Constraints

Figure 3-4 shows a summary of the realistic constraints for the mechanical engineering program.

All the students were able to obtain a minimal level of proficiency for this assignment (80% or better).

4. Formative Assessment of Realistic Constraints

This section summarizes some of the formative student outcomes from the realistic constraint topic. These included environmental concerns. For example:

The materials used for the construction of our machine will include a variety of metals which can be reliable and last quite a long time. This affects the market by recycling metals to help other industries globally as well as promote our own. It may be more expensive, but it could be a great decision to enhance our footprint and keep up with the crises globally with manufacturing efficiency. Our product can also advertise a recycled material design to help this product actually hit the market in places where environmental consideration matters. We will reconvene at the end of the project to make sure this goal was achieved.

In the short term and long term, this high cost of recycled material will make a dent in our predictions of cost and profit. However, it will reduce the cost in the far future as these machines are broken down to be refurbished and used for more products. We also have alternative plans for this prototype project to allow for adjustment and a wide variety of cost to make our budget cheaper and our profit higher. Reusable designs and end products will be more beneficial if a company were to keep including this product in their own lineups. The economy and environment can benefit greatly from this product with its efficiency.

Students were also required to describe the products impact. For example:

The battery assembly glovebox will impact various areas of the world. Economically, the glovebox will provide an efficient way to manufacture and produce high-quality, long-life batteries. The glovebox system will also provide ways to track battery efficiency and lifespan to constantly monitor battery behavior. Regarding the environmental, the increased battery efficiency will make battery powered modes of transportation more attractive. This will help curb greenhouse gas emissions from the transportation sector, and thus, promote a positive environment impact. The social impact includes promoting environment sustainability. In other words, it is our social responsibility to preserve the environment for the next generation. Legal ramifications include preventing the production of faulty batteries. Consumers could pursue lawsuits *if our batteries didn't work in critical devices such as firearms. Ethical concerns include verifying that this project will promote the wellbeing of humanity through its ability to research and develop efficient battery production environments. In addition, the project team members must take steps to mitigate all negative potential repercussions, such as battery waste. Health and safety issues that must be addressed include protecting team members wellbeing while working on the project. For example, ensuring that team members implement measures to curb the spread of Covid-19. Regarding manufacturability, the team must ensure that the batteries and environment from the project glovebox are able to be reproduced at scale on an industrial level. This is essential if portions of this project are going to be adopted by companies. Sustainability of the project includes aspects previously discussed such as environment preservation and waste management.*

Social Impact was also a topic upon which the students were required to touch. For example:

Because it gives patients an option, our gadget will have a positive influence on society. Patients all throughout the globe would be able to get a heart without having to wait months. This will be especially beneficial in nations with a large number of individuals suffering from cardiovascular problems. Although the gadget is pricey, it gives patients an option they have never had before. Those who use our technology will provide others the opportunity to receive a heart from a Donor. The goal of our gadget is to give patients additional time to live. Before being used on actual patients, this gadget will need to go through a number of clinical studies. When it comes to new innovations and processes, there are always certain dangers and complications, but this equipment will be developed to have as little risk as possible. The general public will be affected by this innovative gadget since it offers an alternative to traditional heart transplants. It is intended to give patients with an alternative to the traditional method of obtaining a heart.

Students were asked to address health and safety issues, as a part of the potential constraint on the design. For example:

Human safety and health is at the center of our design. Although there is no human or animal testing required to bring a product like this to market, a user will likely be interacting with dangerous chemicals inside the glove box. With this in mind, we have to follow certain safety standards to ensure that individuals working with batteries within this system won't be exposed to unsafe conditions. One example of safety standards that we are following would be in regards to the leaking of gas from the system. The ISO 20486:2017 Non-destructive testing — Leak testing — Calibration of reference leaks for gases is a standard that will test our system for the baseline of how much gas will leak. Anything over that can be coded into the PLC to alert the user that there is a hazardous amount of gas.

The legal and regulatory constraints on the project also had to be considered. For example:

This project intends to market the finished product both in and outside of the United States. Before the device may be sold in the United States, it must be regulated and approved by the Food and Drug Administration (FDA). Other sections of the world's regulatory agencies will be required to do the same. If necessary, the gadget could be switched out in accordance with the rules of the other regulatory authorities. These

other regulatory bodies could include the European Medicines Agency (EMA) in Europe, the Japanese Pharmaceuticals and Medical Devices Agency (PMDA), and the World Health Organization.
The device aspires to be a huge success. Insurance would be required in the event that the gadget failed. The heart may fail, but clinical trials are required first to test the technology. RoHS compliance is required for this gadget. It is required because the gadget uses an electromechanical stimulus to pump blood through veins.

Students were asked to comment on the manufacturability of their project. For example:

Our product would make use of sustainable materials. Instead of using plastics, we decided to use wood which is more sustainable and environment friendly. Our product would be biodegradable unlike plastic. In building our model, we would cut out the parts ourselves. The manufacturing process is called subtractive manufacturing. Since would need to add sensors to some of our tools, there might be need for injection molding to incorporate these parts into the devices built.
In order to improve the design, we would be looking into CAD software as we would be designing new ideas on the 3D software. To get a more physical copy of the potential design for comparison, we would possibly be 3D printing our draft designs. This would make it easier for visualization of our ideas and analysis of what we anticipate to be results. Overall, because wood can be hard to handle in terms of machinability, our ideas might depend entirely on CAD and 3D printing until we pick a final design just to reduce the waste. It is also safer for our team overall to reduce the amount of time spent in manufacturing.

In summary each student is asked to write an essay touching on the multi-dimensional aspects of the realistic constraints that surround their project. These assessments are organized by major and assessed during program wrap-up sessions.

5. Summary

Each student writes about assessment from their own majors' point-of-view. Students are required to write at least a few sentences about each realistic constraint and describe its' impact upon their project. Students who do not proof-read their writing or who just copy from each-other are required to repeat the assignment. We make use of the "safe-assign" system in order to help prevent plagiarism. A minimal level of proficiency for the summative and formative assignments is 80. Part 3 of this series of papers will address assessment of the major design experience.

6. References

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7. Author information

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