ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #36997

Evaluating ABET Student Outcome (2) in a Multidisciplinary Capstone Project Sequence

Nicholas A Baine (Associate Professor of Engineering)

Nicholas Baine, Ph.D., P.E. is an Associate Professor in the School of Engineering at Grand Valley State University (GVSU). He is the current Chair of the North Central Section of the American Society of Engineering Education and is the faculty adviser for Laker Racing (GVSU's Formula SAE Team). His expertise is in the design of electrical control systems and sensor data fusion. He has done research in a variety of applications, which include integrity monitoring for navigation systems, autonomous ground vehicles, and battery management systems. As an instructor, he specializes in teaching and designing 1st year engineering courses as well as specialized control systems courses.

Evaluating ABET Student Outcome (2) in a Multidisciplinary Capstone Project Sequence

Abstract

In 2017, ABET published a revised list of student outcomes detailed under ABET General Criterion 3, which replaced outcomes (a) through (k) with outcomes (1) through (7). The revised student outcomes place greater emphasis on measuring students' ability to consider a wide range of factors in engineering situations and to address problems in multidisciplinary teams. The wide scope of outcome (2) presents unique challenges. This paper describes an assessment method for ABET student outcome (2), which assesses "…an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors."

The capstone project sequence at Grand Valley State University (GVSU) is well-suited to assess students' ability to apply engineering design on real-world projects, most of which require multidisciplinary teams. To complicate the assessment, ABET requires each program to be assessed independently without data from students of different majors, even when students with multiple majors take the same course. GVSU's emphasis on the use of multidisciplinary teams drawn from multiple engineering programs as well as ABET's new emphasis on cross-disciplinary learning makes this disaggregation of data difficult.

The assessment tools presented in this paper use faculty advisor evaluations to measure key elements of engineering design for outcome (2) in a multidisciplinary industry-sponsored design and build project. These elements include following a design process, developing documentation, developing a design strategy, applying theory, demonstrating creativity, demonstrating holistic thought, developing alternative solutions, and debugging/troubleshooting the final design. In addition to these elements, students' consideration of public health, safety, and welfare is independently evaluated along with other global, cultural, social, environmental and economic factors. The goal of these assessment tools is to disaggregate team performance data to determine an independent metric for each program major and preserve the multidisciplinary nature of the capstone projects.

This paper presents data collection methods for assessing outcome (2) along with methods to analyze that data and determine an independent metric for each program major. Data from the 2019 capstone sequence at GVSU is used to demonstrate these methods. There is also a discussion about the challenges of demonstrating and evaluating student design regarding the multiple considerations mentioned in outcome (2) and how best to integrate the wide variety of constraints into industry sponsored capstone projects. The result of the methods detailed in the paper is a clear, stable, and independent metric that can be used to assess outcome (2) for each program major in a multidisciplinary capstone project.

Introduction

In the revised ABET General Criterion 3 (Student Outcomes), outcomes (a) through (k) have been replaced with (1) through (7). This paper presents methods to measure ABET student outcome (2) which is written as "an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors." [1]

Grand Valley State Univeristy offers six engineering programs: Biomedical Engineering (BME), Computer Engineering (CE), Electrical Engineering (EE), Mechanical Engineering (ME), Product Design and Manufacturing Engineering (PDM), and Interdisciplinary Engineering (IE). Students from all the programs enroll in the same capstone course sequence. Students in this sequence are placed in teams of three to seven to work on a unique industry sponsored, multidisciplinary, design-build-test project under the supervision of a faculty advisor. The projects are completed over the course of two semesters spanning from January to August and traditionally cover topics related to measurement, industrial automation, product design, product testing, inspection, and measurement devices. Capstone projects are proposed by a range of industrial sponsors and are selected to be sufficiently complex, difficult, and multi-disciplinary that they could not be completed by a single student or a small subset of students within a project group.

We considered that ABET outcome (2) could be measured by the student team's success in meeting the needs of the sponsor for the project. Commercial entities have a vested interest in considering the public health, safety, and welfare as well as global, cultural, social, environmental, and economic factors. This interest is enforced through legal, cultural and social pressure. This would generate a pass/fail criterion for the outcome. Binary data would require a large sample size to provide statistical significance and allow actions to be taken based on data. Data providing more levels of discrimination is valuable including the requirement that the data must be disaggregated by engineering discipline for accreditation purposes.

Evaluation Methods

ABET outcome (2), slightly rephrased, requires two actions: First, the student teams must APPLY engineering design; Second, the teams must CONSIDER certain special factors while performing that design.

A team's ability to apply the engineering design process with consideration to all relevant factors is evident in two ways. It will be evident in the work product of the team through the design produced and the project documentation. Requiring student teams to document the manner and metrics that they used to make design decisions serves an important pedagogical purpose in addition to producing an accreditation trail. A team can also be scored by an experienced engineer with a thorough understanding of the technical, economic, and human constraints of their particular project and who was in a position to observe the team through their design process. This is best measured by the observation of a design team's faculty advisor.

ABET defines Engineering Design to be "a process of devising a system, component, or process to meet desired needs and specifications within constraints. It is an iterative, creative, decision making process in which the basic sciences, mathematics, and engineering sciences are applied to convert resources into solutions. Engineering design involves identifying opportunities, developing requirements, performing analysis and synthesis, generating multiple solutions, evaluating solutions against requirements, considering risks, and making trade-offs, for the purpose of obtaining a high-quality solution under the given circumstances." Examples of possible design constraints include "accessibility, aesthetics, codes, constructability, cost, ergonomics, extensibility, functionality, interoperability, legal considerations, maintainability, manufacturability, marketability, policy, regulations, schedule, standards, sustainability, or usability." [1] This definition makes it clear that these considerations are not required, but only constitute examples of factors in a sound engineering design. We interpret outcome (2) to require consideration of "public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors," where 'and' in this sentence means that the design must consider each one.

Using this definition, we used two mandatory criteria to evaluate the application of engineering design:

- Design Process: The members of the student design team are cognizant of and can apply engineering knowledge to identify realistic needs, develop requirements, propose/select possible solutions, create conceptual designs, perform detailed design, create physical realization, and validate performance.
- Design Documentation: Design documentation is thorough and complete with excellent discussion of, or reference to, design procedures, equations, sources of purchased components and bibliographic references.

In order to identify deficiencies and correct problems in students' application of the design process, we also chose to measure seven sub-categories of engineering design:

- Design Strategy: The team members develop a design strategy including a plan of attack, decomposition of work into subtasks, and development of a timetable.
- Theory: The team members apply engineering and/or scientific principles thoroughly and correctly to design practical systems or processes.
- Creativity: The team members suggest new approaches and innovate or improve on previous design work
- Holistic Thought: The team members demonstrate an ability to think holistically; they see the whole as well as the parts.
- Alternative Solutions: The team members develop several potential solutions to find an optimum.
- Integrative Solutions: The team members demonstrate an understanding interrelation between different parts and competently integrate prior knowledge into a new problem.
- Debugging/Troubleshooting: The team members debug or troubleshoot technical problems through logical inference.

We then measure how well the student teams considered each of the requisite factors to the design. These are:

- Public Health, Safety, and Welfare Constraints: The team members develop a solution that includes thorough consideration of public health, safety, and welfare constraints.

- Global Constraints: The team members develop a solution that includes thorough consideration of economic, health & safety, sociopolitical, environmental and manufacturability constraints.
- Cultural Constraints: The team members develop a solution that includes thorough consideration of cultural constraints.
- Social Constraints: The team members develop a solution that includes thorough consideration of social constraints.
- Environmental Constraints: The team members develop a solution that includes thorough consideration of environmental constraints.
- Economic Constraints: The team members develop a solution that includes thorough consideration of economic constraints.

Students were evaluated by their faculty advisor at the conclusion of their design on the basis of their final design documentation, the final design, and their performance throughout the design task. Faculty were provided a rubric which allows them to rate student teams according to a 4-point scale ranging from "Below Performance Expectations" to "Exceeds Performance Criteria" (see faculty assessment rubric Tables 6 and 7).

Calculation and Disaggregation

In ABET's emphasis on holistic design incorporating a wide range of factors, multi-disciplinary design is strongly encouraged and there are strong pedagogical benefits to this approach. However, for the purposes of accreditation, students in each engineering program must be disaggregated. As has been demonstrated for other ABET outcomes, we choose to employ a *post facto* statistical disaggregation to maintain the multidisciplinary character of the capstone design. [2]

In order to disaggregate the team scores to individual programs a team of purely EE students would contribute only to the EE program score, and a team of purely ME student would contribute only to ME program score, and a team composed 50-50 of each would contribute to both equally, but half as much as either the purely EE or ME teams. We used an approach where each project team received a weighting depending upon the program major of the students composing the team. For instance, the scores of a hypothetical multi-disciplinary team composed of two EE students, three ME students, and one CE student would receive a weighting of 2, 3, and 1 toward those programs respectively, while receiving a weighting of 0 to programs which did not include those students. The program score for each individual outcome element is expressed mathematically as:

$$Program\ Score = \frac{\sum_{i=1}^{n} S_i k_i}{\sum_{i=1}^{n} k_i} \qquad (1)$$

where n is the number of teams, S_i is the score on that particular element for the i^{th} team, and k_i is the number of students in that program on the i^{th} team.

Results

In this section, the results from 2019 for an assessment in the capstone project at Grand Valley State University are presented as an example of the instrument along with summative data from 2019-2021. In 2019, there were 127 students participating in the courses and were placed on one of 26 teams. The breakdown of teams is shown in Table 1.

Table 1: Distribution of students from each program major on each team

Team #	1	2	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
EE	0	0	3	0	2	0	2	0	3	2	3	2	0	1	1	4	2	1	1	3	1	3	1	1	0
CE	0	0	2	2	1	0	0	0	0	1	0	2	0	0	2	0	0	1	0	1	0	0	0	1	2
PDM	3	6	0	0	1	1	0	1	1	1	0	1	2	1	1	0	1	1	3	0	1	1	0	2	2
ME	2	0	0	3	2	3	2	3	1	1	3	0	3	3	2	1	2	2	1	1	2	2	5	1	1

Table 2: Team scores from assessment rubric

Team Number	Average	Std. Dev	Min	Max	1	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Design Process	3.60	0.645	2	4	2	3	3	3	4	4	4	4	4	4	4	4	3	4	4	4	4	4	4	2	4	3	4	3	4
Documentation	3.32	0.748	2	4	2	2	2	3	3	4	4	4	3	3	4	3	3	4	4	3	4	4	4	2	4	3	4	3	4
Public Health, Safety, and Welfare Constraints	3.36	0.490	3	4	3	3	3	3	3	3	4	4	3	4	3	3	3	3	4	3	3	4	4	3	4	4	3	4	3
Global Constraints	3.16	0.374	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	4	3	3	3	3	3	3	4	3	3	4
Cultural Constraints	3.04	0.200	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4
Social Constraints	3.04	0.200	3	4	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3
Environmental Constraints	3.16	0.374	3	4	3	3	3	3	3	3	3	3	4	4	3	3	3	3	4	3	3	3	4	3	3	3	3	3	3
Economic Constraints	3.44	0.583	2	4	2	3	3	3	4	4	4	4	4	4	4	3	4	3	4	3	3	3	4	3	4	3	3	3	4
Design Strategy	3.40	0.816	1	4	2	2	3	3	4	4	4	4	3	3	4	4	4	3	4	3	4	4	4	1	4	3	4	3	4
Theory	3.36	0.757	2	4	2	2	3	3	3	4	4	4	4	3	4	4	3	4	4	3	4	4	4	2	3	2	3	4	4
Creativity	3.28	0.678	2	4	2	3	2	3	3	4	3	4	3	3	4	4	3	4	4	3	4	4	4	2	3	3	3	3	4
Holistic Thought	3.28	0.678	2	4	2	2	3	3	3	4	4	4	3	3	4	4	3	3	3	4	4	4	4	2	3	3	3	3	4
Alternative Solutions	3.24	0.723	2	4	2	2	3	4	4	4	3	3	3	4	4	3	2	3	4	3	4	4	4	3	3	3	3	2	4
Integrative Solutions	3.36	0.569	2	4	2	3	3	3	4	4	3	3	3	3	3	3	3	3	4	4	4	4	4	3	3	4	4	3	4
Debugging and Troubleshooting	3.48	0.586	2	4	3	3	2	3	3	4	4	4	4	3	3	4	3	4	4	4	4	4	4	3	3	3	4	3	4
Outcome 2 Total	**3.30**	**0.387**	**2.4**	**3.8**	**2.4**	**2.7**	**2.8**	**3.1**	**3.3**	**3.7**	**3.5**	**3.7**	**3.3**	**3.3**	**3.5**	**3.4**	**3.1**	**3.3**	**3.8**	**3.3**	**3.6**	**3.7**	**3.8**	**2.5**	**3.3**	**3.2**	**3.3**	**3.1**	**3.8**

Table 2 displays the scores for each element as scored by each team's faculty advisor using the assessment rubric in Tables 6 & 7. While the average of all outcome element scores were above a 3, which is defined as "Meets Performance Criteria", it is clear that the elements that assessed the ability to design to global, cultural, social, and environmental constraints were the weakest.

To determine the scores for the computer engineering program, the scores from Table 2 were weighted by the number of CE students in each program (Table 1) using equation (1). The result of this calculation is shown in Table 3. For the 2019 assessment, the average element score for CE was 3.31 with *social constraints* and *cultural constraints* being the two weakest elements with scores of 3.00 and 3.13, respectively. The *Design Process* and *Alternative Solutions* were found to be the strongest.

Table 3: Weighted faculty assessment scores for CE program majors

Team Number		**1**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**
Number of CE Students in Team		0	0	2	2	1	0	0	0	0	1	0	2	0	0	2	0	0	1	0	1	0	0	0	1	2
Outcome Element	**Average**	Scores for each team are weighted by the number of students in the major assessed																								
Design Process	3.53	0	0	6	6	4	0	0	0	0	4	0	8	0	0	8	0	0	4	0	2	0	0	0	3	8
Documentation	3.13	0	0	4	6	3	0	0	0	0	3	0	6	0	0	8	0	0	4	0	2	0	0	0	3	8
Public Health, Safety, and Welfare Constraints	3.33	0	0	6	6	3	0	0	0	0	4	0	6	0	0	8	0	0	4	0	3	0	0	0	4	6
Global Constraints	3.27	0	0	6	6	3	0	0	0	0	3	0	6	0	0	8	0	0	3	0	3	0	0	0	3	8
Cultural Constraints	3.13	0	0	6	6	3	0	0	0	0	3	0	6	0	0	6	0	0	3	0	3	0	0	0	3	8
Social Constraints	3.00	0	0	6	6	3	0	0	0	0	3	0	6	0	0	6	0	0	3	0	3	0	0	0	3	6
Environmental Constraints	3.20	0	0	6	6	3	0	0	0	0	4	0	6	0	0	8	0	0	3	0	3	0	0	0	3	6
Economic Constraints	3.40	0	0	6	6	4	0	0	0	0	4	0	6	0	0	8	0	0	3	0	3	0	0	0	3	8
Design Strategy	3.40	0	0	6	6	4	0	0	0	0	3	0	8	0	0	8	0	0	4	0	1	0	0	0	3	8
Theory	3.47	0	0	6	6	3	0	0	0	0	3	0	8	0	0	8	0	0	4	0	2	0	0	0	4	8
Creativity	3.27	0	0	4	6	3	0	0	0	0	3	0	8	0	0	8	0	0	4	0	2	0	0	0	3	8
Holistic Thought	3.27	0	0	6	6	3	0	0	0	0	3	0	8	0	0	6	0	0	4	0	2	0	0	0	3	8
Alternative Solutions	3.53	0	0	6	8	4	0	0	0	0	4	0	6	0	0	8	0	0	4	0	3	0	0	0	2	8
Integrative Solutions	3.40	0	0	6	6	4	0	0	0	0	3	0	6	0	0	8	0	0	4	0	3	0	0	0	3	8
Debugging and Troubleshooting	3.33	0	0	4	6	3	0	0	0	0	3	0	8	0	0	8	0	0	4	0	3	0	0	0	3	8
Outcome 2 Average	**3.31**			3	3	3					3		3			4			4		3				3	4

Table 4 shows the element scores and average element score for each program major in 2019. Based on the assessment, the *Cultural Constraints* and *Social Constraints* elements were consistently the weakest from all program majors.

Table 4: Assessment averages by program major

Outcome Element	**All Majors**	**ME**	**EE**	**CE**	**PDM**
Design Process	3.60	3.67	3.64	3.53	3.43
Documentation	3.32	3.57	3.19	3.13	3.10
Public Health, Safety, and Welfare Constraints	3.36	3.35	3.33	3.33	3.37
Global Constraints	3.16	3.17	3.11	3.27	3.17
Cultural Constraints	3.04	3.02	3.00	3.13	3.07
Social Constraints	3.04	3.04	3.08	3.00	3.03
Environmental Constraints	3.16	3.11	3.19	3.20	3.20
Economic Constraints	3.44	3.48	3.42	3.40	3.37
Design Strategy	3.40	3.59	3.28	3.40	3.20
Theory	3.36	3.41	3.31	3.47	3.17
Creativity	3.28	3.37	3.14	3.27	3.30
Holistic Thought	3.28	3.33	3.33	3.27	3.03
Alternative Solutions	3.24	3.30	3.31	3.53	2.93
Integrative Solutions	3.36	3.41	3.42	3.40	3.27
Debugging and Troubleshooting	3.48	3.57	3.42	3.33	3.43
Outcome 2 Total	**3.30**	**3.36**	**3.28**	**3.31**	**3.20**

Table 5 shows the average score for each element and the average element score for three years (2019-2021). This data was explored to look for trends among the elements. It was found that scores dropped in 2020 and 2021, with pandemic restrictions being a contributing factor.

Table 5: Assessment averages for all program majors by year (2019-2021)

Outcome Element	All years	2019	2020	2021
Design Process	3.49	3.60	3.62	3.24
Documentation	3.29	3.32	3.28	3.28
Public Health, Safety, and Welfare Constraints	3.23	3.36	3.22	3.12
Global Constraints	2.94	3.16	2.67	3.00
Cultural Constraints	2.80	3.04	2.57	2.80
Social Constraints	2.85	3.04	2.66	2.84
Environmental Constraints	3.06	3.16	3.10	2.92
Economic Constraints	3.43	3.44	3.60	3.24
Design Strategy	3.47	3.40	3.72	3.28
Theory	3.22	3.36	3.26	3.04
Creativity	3.33	3.28	3.52	3.20
Holistic Thought	3.31	3.28	3.48	3.16
Alternative Solutions	3.24	3.24	3.43	3.04
Integrative Solutions	3.45	3.36	3.66	3.32
Debugging and Troubleshooting	3.40	3.48	3.41	3.32
Outcome 2 Total	**3.23**	**3.30**	**3.28**	**3.12**

Discussion

The measured results show that students' capacity for engaging in complex design thinking is adequate overall, but there are areas that need improvement. We observed that students of engineering programs of all types performed worse in their consideration of global, cultural, and social constraints (2.94, 2.80, and 2.85 respectively, versus a 3.23 average), which are relatively new to ABET student outcome (2), formerly outcome (c). While this is a weakness of all engineering programs, we observed them to be consistently lower in the EE and CE programs.

We consider that there are several hypotheses to explain this observation. One possibility is that there is a perception among electrical engineering and computer engineering students and faculty that their projects are fairly constrained, often focusing on software or limited prototypes and test articles, do not usually have an obvious impact on the supply chain, and do not substantially alter manufacturing operations. There is some anecdotal evidence to believe this is true. While differences with other cultures have entered into consideration of several projects (such as an expected delay when receiving parts from China in February, or from France in August), many faculty advisors expressed confusion over how to incorporate or assess considerations into project designs as varied as 'machine tools for steel bending' to 'systems to measure fluorescent decay times.' Feedback from students and faculty questioned what we could teach student teams about cultural considerations without simply perpetuating crude stereotypes ("Americans are loud and Italians are late."). Some were even more perplexed as to what a 'social constraint' might entail beyond what is considered socially acceptable or not ("Does this mean we can't experiment on prisoners?").

After the initial assessment in 2019, we looked to ABET for examples of teaching cultural and social factors in engineering which are provided by them in their Issue Briefs. In a Fall 2018 issue [3], ABET discusses their intent when increasing the focus on global, cultural, and social considerations. The article considers the example of Engineers Without Borders and several universities' work in impoverished communities in developing nations; however, little guidance is provided for addressing these issues when not working in foreign nations. While these methods of service learning are important to provide when possible, they are not an accurate representation of projects and work most students will experience when they enter the work force and are not representative of the industry sponsor projects available to students in the capstone design sequence. Other ideas of incorporating global, cultural, and social factors we found to be either superficial [4], or impractical [5].

At Grand Valley State Univeristy, senior projects are predominantly multidisciplinary and industry sponsored. The course sequence is designed to give students a realistic experience of engineering design on a project at a typical US firm. The students are given a project description and access to the industry sponsor. Usually, the client is a local company with a problem that needs to be solved which may include the design of a machine to automate a manufacturing process, an R&D project to refine a design, or a product development. Some projects will eventually be in the hands of the general public, but most will only impact a handful of workers in a factory, test facility, or design bench. This presents a significant barrier to assessing outcome (2).

A senior capstone course is the best place to make a summative assessment of a student's ability to perform engineering design with projects complex enough to include a wide variety of specifications and constraints. The use of multidisciplinary industry sponsored projects is the gold standard and will best prepare students for engineering jobs, yet the examples provided by ABET in literature and other examples are all based on carefully constructed student experiences and non-profit activities. In response to this, GVSU's School of Engineering began offering a junior level course to encourage consideration of global, social, cultural, environmental, and economic factors; however, this has had more of an impact on student outcome (4) regarding ethics but had limited success in (2) as students struggle to apply this to all design problems regardless of the relevance.

What sets global, social, and cultural factors apart is a lack of guidance on how to incorporate them into a design. As ABET states, "Engineering design is a process of devising a system, component, or process to meet desired needs and specifications within constraints." Environmental, health, and safety factors are easily incorporated due to existing policies, legal considerations, regulations, and standards; however, global, social, and cultural factors are not easily translated into specifications or constraints in many projects. While it is possible to provide students with experiences that involve these factors, the absence of an agreed upon metric makes these three factors difficult to incorporate in design projects and assess students' ability to consider them.

We will present ideas to better measure and incorporate instruction of global, social, and cultural design constraints during the presentation period with the hope that the subsequent discussion will benefit future works.

Conclusion

This paper presented a method to measure ABET student outcome (2) in a multi-disciplinary capstone design course. We found that the method worked well in assessing the outcome and delivering a disaggregated result, but we also found that assessing how well a design project incorporates a consideration of global, social, and cultural factors is challenging and an area that needs further improvement. The literature is quite clear about the motivation of including global, cultural, and social factors (utilizing engineering to make the world a better place for everyone); however, it is relatively silent on how to incorporate them into measurable specifications or constraints on typical engineering projects with few stakeholders. While design methods are well documented and have been taught for years, designing with consideration of global, social, and cultural factors is relatively new. There remain some major questions of how to incorporate these considerations into most design projects and what metrics can be used to evaluate them.

References

[1] ABET Engineering Accreditation Commission, "Criteria for Accrediting Engineering Programs, 2021-2022," 2022.

[2] Baine, Brakora, Pung, “Evaluating ABET Student Outcome (5) in a Multidisciplinary Capstone Project Sequence,” *in Proceedings of the 2020 ASEE Annual Conference*, 2020

[3] “Sustainable Education: Readying Today’s Higher Ed Students to Tackle the World’s Grand Challenges.” ABET Issue Brief, Fall 2018.

[4] Detwiler, “2019-2020 ABET Criteria for Student Outcomes,” Beton Consulting Engineers LLC, 2019.

[5] Cunningham, “Why do I have to know this? Engineering in a globalized society,” Honors Thesis, *Bucknell University*, Spring 2020.

Table 6: Assessment Rubric Part 1

Assessment Rubric

Outcome element	1 Below Performance Expectations	2 Progressing to Performance Criteria	3 Meets Performance Criteria	4 Exceeds Performance Criteria
Design Process	Is neither cognizant of, nor able to apply engineering knowledge to identify realistic needs, develop requirements, propose/select possible solutions, create conceptual designs, perform detailed design, create physical realization, and validate performance	Is somewhat cognizant of, but has great difficulty in applying engineering knowledge to identify realistic needs, develop requirements, propose/select possible solutions, create conceptual designs, perform detailed design, create physical realization, and validate performance	Is cognizant of, but has some difficulty in applying engineering knowledge to identify realistic needs, develop requirements, propose and select possible solutions, create conceptual designs, perform detailed design, create physical realization, and validate performance	Is cognizant of and can apply engineering knowledge to identify realistic needs, develop requirements, propose/select possible solutions, create conceptual designs, perform detailed design, create physical realization, and validate performance
Documentation	Design documentation is very inadequate or incomplete, without proper discussion or reference to equations, sources of purchased components or bibliographic references	Design documentation is somewhat inadequate or incomplete, without proper discussion of or reference to design procedures, equations, sources of purchased components or bibliographic references	Design documentation is adequate and complete, with perhaps some minor lapses in discussion of or reference to design procedures, equations, sources of purchased components or bibliographic references	Design documentation is thorough and complete with excellent discussion of, or reference to, design procedures, equations, sources of purchased components and bibliographic references
Public Health, Safety & Welfare Constraints	No consideration of public health, safety, and welfare constraints	Includes only minor or cursory consideration of public health, safety, and welfare constraints	Includes adequate consideration of public health, safety, and welfare constraints	Develops a solution that includes thorough consideration of public health, safety, and welfare constraints
Global Constraints	No consideration of global constraints	Includes only minor or cursory consideration of global constraints	Includes adequate consideration of global constraints	Develops a solution that includes thorough consideration of economic, health & safety, sociopolitical, environmental and manufacturability constraints
Cultural Constraints	No consideration of cultural constraints	Includes only minor or cursory consideration of cultural constraints	Includes adequate consideration of cultural constraints	Develops a solution that includes thorough consideration of cultural constraints
Social Constraints	No consideration of social constraints	Includes only minor or cursory consideration of social constraints	Includes adequate consideration of social constraints	Develops a solution that includes thorough consideration of social constraints
Environmental Constraints	No consideration of environmental constraints	Includes only minor or cursory consideration of environmental constraints	Includes adequate consideration of environmental constraints	Develops a solution that includes thorough consideration of environmental constraints
Economic Constraints	No consideration of economic constraints	Includes only minor or cursory consideration of economic constraints	Includes adequate consideration of economic constraints	Develops a solution that includes thorough consideration of economic constraints

Table 7: Assessment Rubric Part 2

Assessment Rubric

Outcome element	1 Below Performance Expectations	2 Progressing to Performance Criteria	3 Meets Performance Criteria	4 Exceeds Performance Criteria
Design Strategy	No design strategy; applies haphazard approach	Uses a design strategy, but requires extensive guidance	Uses a design strategy but requires some guidance	Develops a design strategy, including a plan of attack, decomposition of work into subtasks, and development of a timetable
Theory	No application of engineering and/or scientific principles in the design process	Applies engineering and/or scientific principles incompletely or incorrectly to design practical systems or processes	Applies engineering and/or scientific principles adequately and correctly to design practical systems or processes	Applies engineering and/or scientific principles thoroughly and correctly to design practical systems or processes
Creativity	Cannot innovate/improve upon previous designs, nor can follow a previous design example competently	Does not include any design innovations, but can follow a previous example competently	Can include small design innovations, while following a previous example competently	Suggests new approaches and innovates/improves on previous design work
Holistic Thought	Has no concept of the design, system or process as a sum of its parts	Does not think holistically, tends to see only the pieces; does not see the integration of the pieces clearly	Has some difficulty thinking holistically; does not always see the integration of all the pieces clearly	Thinks holistically: sees the whole, as well as the parts
Alternative Solutions	Only focuses on one solution to a problem; no optimization attempted	Can develop and compare multiple solutions to a problem, but does not usually arrive at the best result; conducts optimization but neglects one or two key aspects	Can develop and compare multiple solutions to a problem, but does not usually arrive at the optimum result; conducts optimization but neglects one or two key aspects	Develops several potential solutions and finds optimum
Integrative Solutions	Unable to relate prior knowledge to the design problem	Can use prior knowledge to competently design individual pieces of equipment, when guided to do so	Can use prior knowledge to competently design individual pieces of equipment, when guided to do so	Understands how areas interrelate and demonstrates ability to competently integrate prior knowledge into a new problem
Debugging/Troubleshooting	Makes no attempt at debugging/ troubleshooting a technical problem by logical deduction; immediately asks for help	Needs extensive direction in debugging/troubleshooting a technical problem by logical deduction	Needs some direction in debugging/troubleshooting a technical problem by logical deduction	Can debug/troubleshoot a technical problem by logical deduction