Fairfield UNIVERSITY

International Journal of Computer and Systems Engineering

Volume 3 | Issue 1 Article 1

January 2022

ABET Assessment Part 3: Societal Impact and Sustainability

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Recommended Citation

Lyon, Douglas A. (2022) "ABET Assessment Part 3: Societal Impact and Sustainability," *International Journal of Computer and Systems Engineering*: Vol. 3: Iss. 1, Article 1.
Available at: https://digitalcommons.fairfield.edu/ijcase/vol3/iss1/1

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International Journal of Computer and Systems Engineering

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Vol. 2, No. 3, April 2022

ABET Assessment Part 3: Societal Impact and Sustainability

This paper describes outcome assessment tactics for ABET

by Douglas Lyon, Ph.D. and Caroline Neilson

Abstract

This paper establishes an assessment framework for compliance with the general ABET criteria for impact and sustainability. This paper is part 3 of a multi-part series of papers on the assessment of student outcomes for senior design projects. The methodology established in this series of papers may serve as a model for engineering-program compliance with select ABET criteria. Part 1 of this multi-part series addressed student-outcome assessment in the area of standards. Part 2 addressed the outcomes of assessment in the area of realistic constraints.

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 programs to 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 the "appropriate engineering standards and multiple constraints" criterion? Where should the standards and constraints outcomes be measured? How do we assess impact and sustainability through student outcomes? How can we have a program-oriented measurement of these things when we have interdisciplinary teams?

Douglas A. Lyon: "The Rise of Ryzen", in *International Journal of Computer and Systems Engineering*, Volume 1, Issue 1, August 2020. http://www.

Direct examination of student work is only effective on a team-oriented basis when the team is from the same program. Thus interdisciplinary teams confound program-oriented evaluation and yet interdisciplinary teams provide intrinsic value that many programs have embraced.

We are motivated to study this problem because it impacts 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 in the 2020-2021 time frame. Thus, this is an international and widely felt problem [ABET].

2. Approach

Parts 1 and 2 of this series of papers describe the assessment of standards and realistic constraints. In this part 3, we cover the assessment of impact and sustainability in the senior design project. We use BlackBoard, to perform both summative and formative assessments. The summative aspect is graded automatically through the BlackBoard system. The formative assessment measures student performance using a free-form English narrative.

3. Local and Global Societal Impact

This section is subdivided into two parts. Section 3.1 discusses the summative assessment of local and global societal impact. Section 3.2 describes our formative assessment of local-global impact.

3.1 Summative Assessment

This section describes the summative assessment of student outcomes in the area of societal impact. The assessment is summarized by the program. BlackBoard enables automated summative assessment via a computer-implemented answer key. Sample questions appear below:

1) How many gallons of motor gasoline does the average American consume in one year?
   a) 150 gallons
   b) 500 gallons
   c) 310 gallons
   d) 750 gallons

2) (True/False) Biodiversity is the variety of ecosystems on Earth
3) Of the following indications of the health of a water body, which is the most widely accepted means of measuring how polluting an effluent is?
   a) BOD (biological oxygen demand)
   b) COD (chemical oxygen demand)
   c) Chloroform content
4) Which of the following sources of energy is NOT renewable?
   a) Petroleum
   b) Hydro Power
   c) Biomass
   d) Solar power

5) Name of the International agreement by 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions
   a) Timeplex Protocol
   b) Kyoto protocol
   c) Green Protocol
6) What is the most serious threat to biodiversity?
   a) Habitat loss
   b) Tourists
   c) Pollution
7) The industry responsible for the greatest anthropogenic (human activity related) release of methane into the atmosphere is:
   a) Energy
   b) Transportation
   c) Agriculture
   d) Waste Treatment
8) Three key areas of sustainability are…
   a) Political, energy, and recycling
   b) Economic, social, and political
   c) Social, environmental and economic
   d) Recycling, biodiversity, and social
9) (True/False) Climate change only started with the Industrial Revolution.
10) Which of the following is NOT a strategy for increasing Earth's sustainability?
   a) Crop rotation
   b) Using recycled materials
   c) Designating land as wilderness
   d) Increasing the size of industrial farms
11) Which of the following best describes economic sustainability?
   a) Investments in internal technology
   b) Focusing sales to market needs
   c) Anti-corruption policies
   d) Corporate citizenship
12) Which of the following lowers your carbon footprint?
   a) Riding a bike to College
   b) Driving a car to the shops
   c) Taking a plane to Spain
13) Improving education opportunities can help (check all that apply):
   a) Improve family planning options
   b) Reduce poverty
   c) Increase family size
   d) Prevent destruction of natural habitats
14) According to the 2009 Greening of Corporate America research study, what is a driver of sustainability today?
   a) Profitable growth
   b) Protecting the environment and improving quality of life

c) Market differentiation
d) All of the above

15) Which country is overall the highest emitter of CO_2 at the moment?
a) United States of America
b) China
c) Brazil

16) Providing good conditions for workers is:
a) Not important
b) A moral issue
c) A design issue
d) A recycling issue

17) How can consumers help promote supply chain transparency?
a) Buying garments that meet environmental certifications
b) Purchasing garments from big-box retailers
c) Buying garments made locally or made in the USA
d) Buying garments that meet environmental certifications and Buying garments that meet environmental certifications

18) (True/False) Sustainability is the use of a resource that doesn't cause long-term depletion of the resource or affect the diversity of the ecosystem.

3.2 Formative Assessment

This section describes our formative assessment approach to local and global societal impact. Students submit an essay whose template follows:

Name:
Project name:
Major:
At least two paragraphs about the following topics:
Product Impact
Economics and Environmental Impact
Social Impact
Legal Ramifications
Ethical Concerns
Health and Safety Issues
Manufacturability
Sustainability

These submissions are tested using the SafeAssign plagiarism detection tool built into BlackBoard and then assessed manually.

4. Sustainability

This section describes a summative assessment of sustainability. We start with a series of questions that can be automatically graded through Blackboard.

4.1 Summative Assessment

1) How many gallons of motor gasoline does the average American consume in one year?
    a) 150 gallons
    b) 500 gallons
    c) 310 gallons
    d) 750 gallons
2) (True/False) Biodiversity is the variety of ecosystems on Earth
3) Of the following indications of the health of a water body, which is the most widely accepted means of measuring how polluting an effluent is?
    a) BOD (biological oxygen demand)
    b) COD (chemical oxygen demand)
    c) Chloroform content
4) Which of the following sources of energy is NOT renewable?
    a) Petroleum
    b) Hydro Power
    c) Biomass
    d) Solar power
5) Name of the International agreement by 37 industrialized countries and the European community for reducing greenhouse gas (GHG) emissions
    a) Timeplex Protocol
    b) Kyoto protocol
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6) What is the most serious threat to biodiversity?
    a) Habitat loss
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    c) Pollution
7) The industry responsible for the greatest anthropogenic (human activity related) release of methane into the atmosphere is:
    a) Energy
    b) Transportation
    c) Agriculture
    d) Waste Treatment
8) Three key areas of sustainability are…
    a) Political, energy, and recycling
    b) Economic, social, and political
    c) Social, environmental and economic
    d) Recycling, biodiversity, and social
9) (True/False) Climate change only started with the Industrial Revolution.
10) Which of the following is NOT a strategy for increasing Earth's sustainability?
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    b) Using recycled materials
    c) Designating land as wilderness

d) Increasing the size of industrial farms

11) Which of the following best describes economic sustainability?
    a) Investments in internal technology
    b) Focusing sales to market needs
    c) Anti-corruption policies
    d) Corporate citizenship
12) Which of the following lowers your carbon footprint?
    a) Riding a bike to College
    b) Driving a car to the shops
    c) Taking a plane to Spain
13) Improving education opportunities can help (check all that apply):
    a) Improve family planning options
    b) Reduce poverty
    c) Increase family size
    d) Prevent destruction of natural habitats
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    a) Profitable growth
    b) Protecting the environment and improving quality of life
    c) Market differentiation
    d) All of the above
15) Which country is overall the highest emitter of CO_2 at the moment?
    a) United States of America
    b) China
    c) Brazil
16) Providing good conditions for workers is:
    a) Not important
    b) A moral issue
    c) A design issue
    d) A recycling issue
17) How can consumers help promote supply chain transparency?
    a) Buying garments that meet environmental certifications
    b) Purchasing garments from big-box retailers
    c) Buying garments made locally or made in the USA
    d) Buying garments that meet environmental certifications and Buying garments that meet environmental certifications
18) (True/False) Sustainability is the use of a resource that doesn't cause long-term depletion of the resource or affect the diversity of the ecosystem.

4.2 Formative Assessment

This section describes our formative assessment approach to sustainability as well as local and global societal impact. Students submit an essay whose template follows:

Name:

Project name:
Major:
At least two paragraphs about the following topics:
Product Impact
Economics and Environmental Impact
Social Impact
Legal Ramifications
Ethical Concerns
Health and Safety Issues
Manufacturability
Sustainability

These submissions are tested using the SafeAssign plagiarism detection tool built into BlackBoard and then assessed manually.

5 Results

5.1 Summative Assessment Results

Figures 1-4 show the results of summative assessment of student outcomes from Societal Impact and Sustainability separated into Biomedical, Computer Science, Electrical, and Mechanical programs.

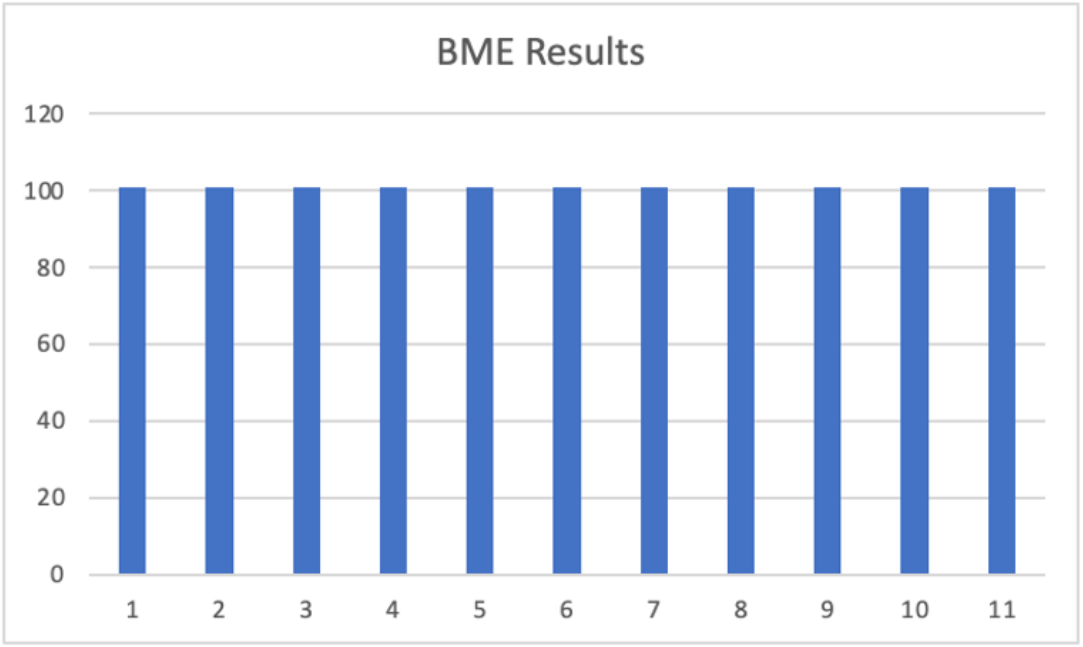

Figure 1. BME Local and Global Societal Impact

Figure 1 shows the summative results from Societal Impact and Sustainability by students from the biomedical engineering program. According to the data collected, students within the biomedical engineering program returned perfect scores.

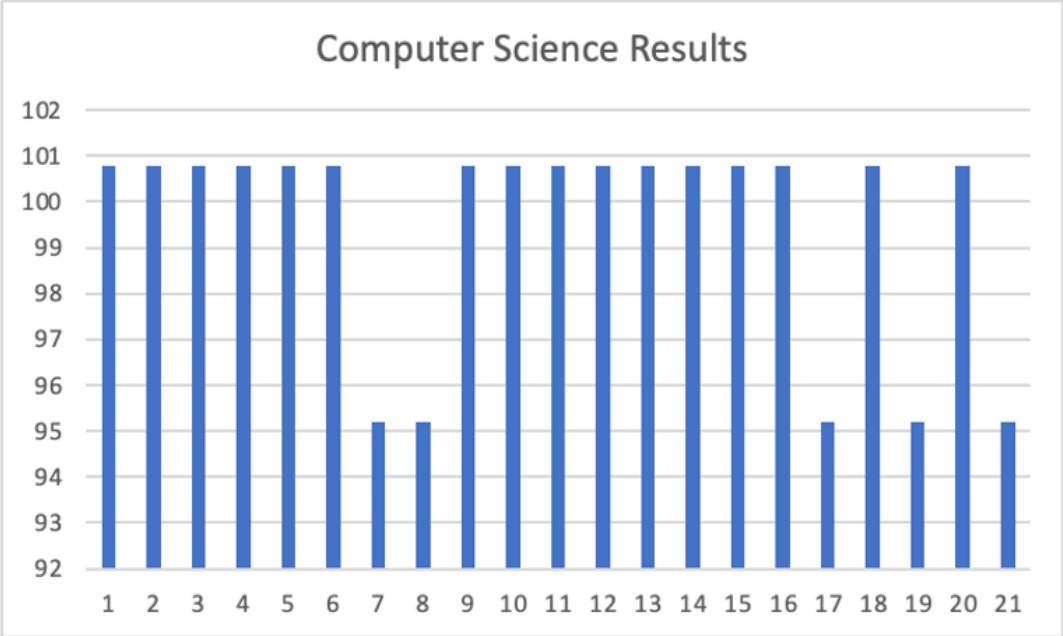

Figure 2. CS Local and Global Societal Impact

Figure 2 shows the summative results from Societal Impact and Sustainability by students from the computer science program. According to the data collected, 76% of students within the computer science program returned perfect scores upon completion.

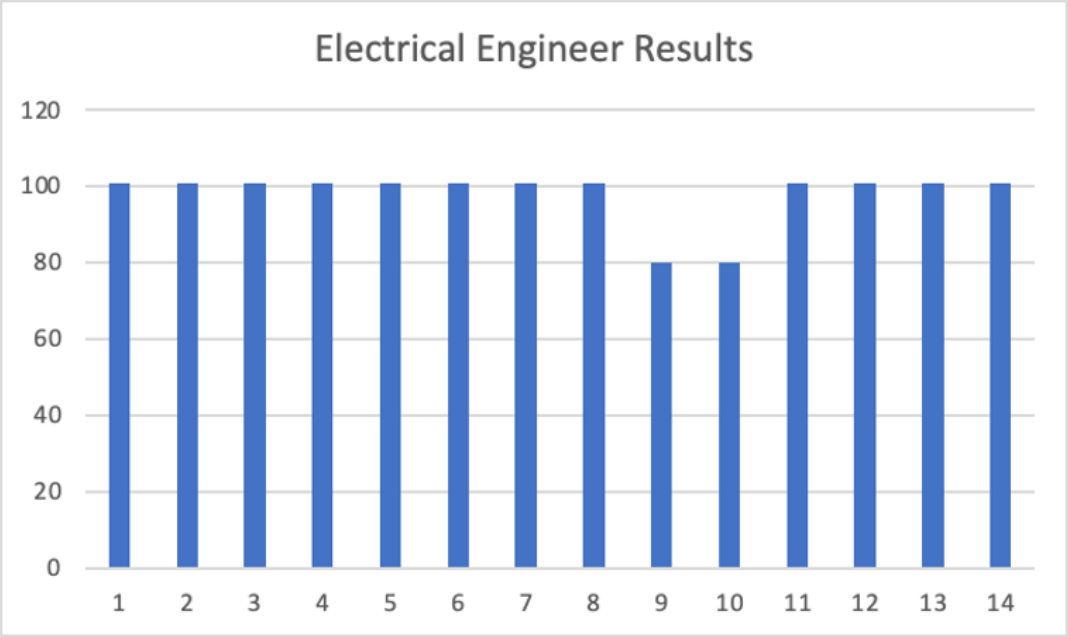

Figure 3. EE Local and Global Societal Impact

Figure 3 shows the summative results from Societal Impact and Sustainability by students from the electrical engineering program. According to the data collected, 85.7% of students within the electrical engineering program returned perfect scores upon completion.

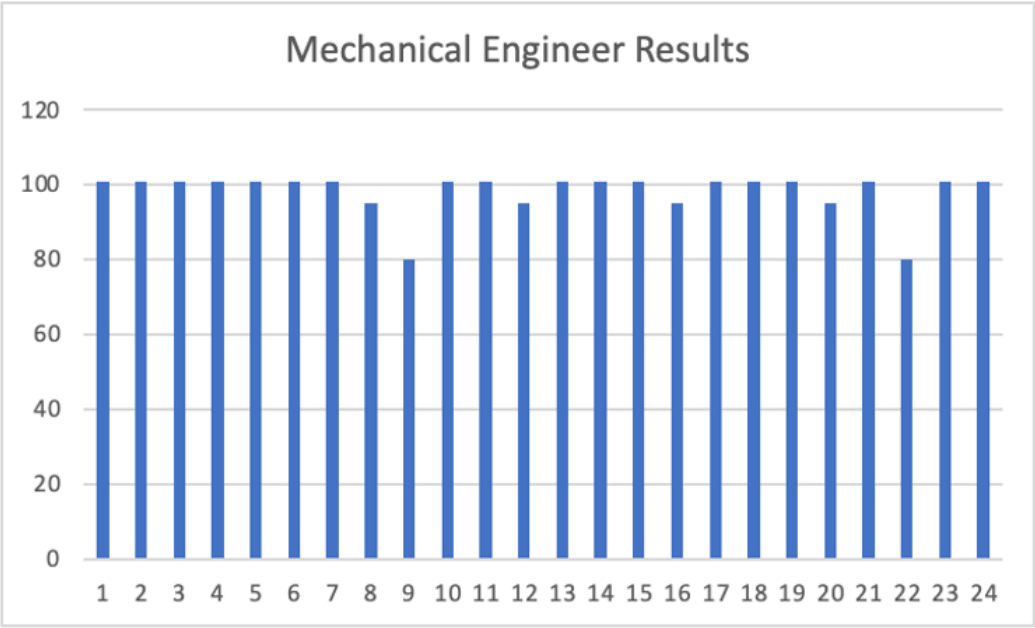

Figure 4. ME Local and Global Societal Impact

Figure 4 shows the summative results from Societal Impact and Sustainability by students from the mechanical engineering program. According to the data collected, 85.7% of students within the electrical engineering program returned perfect scores upon completion.

5.2 Formative Assessment Results

The excerpts below show the results of a summative assessment of student outcomes from Societal Impact and Sustainability from students of the Biomedical, Computer Science, Electrical, and Mechanical programs. For safety reasons, names have been omitted from the name section of the essay.

> Your Name:
> Your Project Name: RBI Project (Standalone Particle Inspection System)
> Your Major: Mechanical Engineering
> 2.1 Economics and Environmental Impact
> Sustainability, reusability, and a long-term lifespan are what we focused on and discussed in our SPIS design. In order to accomplish low economic and environmental impacts, our machine is comprised of recycled metals. This serves as a durable yet eco-friendly method in designing our product to match the best working criteria. In regards to the short-term versus long-term effects of choosing recycled materials, there are many negative consequences. Consideration must be given to the manufacturability, sterilization, and market cost. The downside of incorporating recycled materials is that the value of the material follows a supply and demand curve. In some cases metals like copper and brass, receive a higher recycled value than at the time they were produced. This is best exemplified during the pandemic when we saw a tremendous increase in all raw materials,

due to the lack of production. Another downside to this is the impact on manufacturing capacity if the material supply is altered. Additionally, since the material is recycled extra costs must be allocated to the sterilization process. Significant increases in cost are seen when wagering the economic and environmental impact of one's design.

2.2 Social Impact

Our system will undoubtedly have a positive impact on society by providing detailed lithography inspections for all ASML's semiconductors and reticle fabrications. This, in turn, will increase the efficiency of production and the global demand. ASML is the leader in the semiconductor industry accomplishing billions of dollars in sales each year. Creating a product that advances the quality and time of delivery will yield benefits to both the consumer and supplier. In turn, this lasting impact will abolish competition within the industry and encourage newer technologies each year. By implementing our SPIS the consumer will experience less risk and complications. Acknowledging that ASML fuels communication systems, hospital technologies, and military innovations, cultivates a sense of trust in what you are integrating. Due to efforts on both sides of the line, a decrease in the number of injuries and deaths may be seen. Few defects will pass through the manufacturing stages providing positive effects on the general public.

2.3 Legal Ramifications

The Standalone Particle Inspection System will require federal regulatory agencies to be involved with the sale of this product. Such agencies include independent ones such as the Consumer Product Safety Commission, which addresses the risks of injury and safety standards in newly developed products. Agencies such as the FDA or FCC would likely not be involved with this process. In order to achieve our goal of product distribution and manufacturing of the SPIS, we would need to comply with European directive 2006/42/EC. This embodies all the necessary conformity requirements our system must meet in order to sell our product. If the SPIS were to make it into the sell and distribution phase worldwide, I would suggest gaining product liability insurance. This is to both protect our company's assets as well as provide firm evidence for the reliability of our product. The product liability insurance works by protecting your business against third parties relating to personal injury caused by your products. Taking into account the monetary value of the SPIS production, we would estimate the cost to be well over hundreds of thousands of dollars. Having that damage control under your shoulders would not hurt the production or sale one bit.

2.4 Ethical Concerns

Throughout the entire design to the production phase of the Standalone Particle Inspection System, we do not predict to encounter any ethical concerns. Of course, there is always the case in which things may go south, but with thorough detailing and communication plans, this can all be avoided. The SPIS will not have insufficient, human, or animal testing. Additionally, there will be a frame and sheet metal enclosing the system so that nothing poses a threat to human safety or health. Our mechanical movement will be isolated so that even with the sheet panel removed for viewing, safety protocols restrict any movement. By

doing so, the ethical concerns surrounding a newly developed product should not hinder us in any way. In regard to the environmental impact of our project, we must ensure that all the materials and components we outsource are safe. To do so, we have been researching other competitors' footprints and are working closely to reduce ours by even more. As supporters of the United Nations net zero emissions by 2050 plan, we hope to contribute our knowledge and strategies to all. Each year technology brings us closer and closer to this goal, and it should influence our environmental ethical obligation.

6 Course PEOs

Excerpts 1-4 show student reactions to the course program's educational objectives. Student responses are categorized by major and have the ability to remain anonymous in their writing.

> "Biomedical engineering alumni of Fairfield were all employed or accepted into graduate school by graduation of 2021. I feel that the alumni in this program have demonstrated that they are successful post undergraduate studies with successful careers, research, or enrollment in graduate school. All the alumni who I have personally encountered demonstrate their excellent communicational and leadership skills which has allowed them to obtain successful careers."

Excerpt 1. BME Response

Excerpt 1 shows a biomedical engineering student's reaction to the course and their preparedness to leave an educational environment.

> "I love my major and I want to start my own business as a tech and lifestyle aid electromechanical technologies. I feel that this program provides me with sufficient knowledge of how to begin a business and how to utilize my own learning and technical skills. I plan to study for my master's in this field and continue with my capital ventures. I feel prepared and confident that I can succeed with what I have been taught in this program. I feel unstoppable."

Excerpt 2. EE Response

Excerpt 2 shows an electrical engineer student's reaction to the course and their preparedness to leave an educational environment.

> "I think we need to do include more of real life engineering experiences, however I do think that I will be able to Engage in lifelong learning by contributing to their chosen field, actively participating in professional societies and broadening their professional knowledge with formal and/or informal continuing education. I also agree with Pursue engineering careers or advanced studies in mechanical engineering or related technical fields."

Excerpt 3. ME Response

Excerpt 3 shows a mechanical engineer student's reaction to the course and their preparedness to leave an educational environment.

> "Broadly speaking, the above Program Educational Objectives fit my major well. I do believe that I have been taught how to succeed when working in a team, how to apply ethics to ensure that my work serves the greater good, and I can say for certain that I have

> been encouraged to always learn more about the ever-expanding world of computer science. However, although I believe that I have been well-prepared to meet the demands of the working world, it would be remiss not to mention that my current skills do not seem to exactly match those required by job applications. I am confident that the skills that I have learned from my major will be useful in the working world, but it has largely been left up to me to decide how to use them effectively (and how to prove to others that I can, indeed, use my skills effectively)."

Excerpt 4. CS Response

Excerpt 4 shows a computer science student's reaction to the course and their preparedness to leave an educational environment.

7 Conclusion

Part one of this series of papers Address the assessment of standards. Part two of this series of papers Address the assessment of realistic constraints. This paper, part three, describes the use of summative and formative assessment of student outcomes in the areas of societal impact and sustainability. Blackboard enables us to formulate automated summative assessment by program. While formative assessment is input via blackboard and checked via safe assign, grading is still a labor intensive process and is likely to remain so for the foreseeable future.

8 Author Information

Douglas A. Lyon received the Ph.D., M.S. and B.S. degrees in computer and systems engineering from Rensselaer Polytechnic Institute (1991, 1985 and 1983). Dr. Lyon has worked at AT&T Bell Laboratories at Murray Hill, NJ and the Jet Propulsion Laboratory at the California Institute of Technology, Pasadena, CA. He is currently an ABET Commissioner, a life member of the IEEE and President of DocJava, Inc., a consulting firm in Connecticut. Dr. Lyon has authored or co-authored four books and over 50 journal publications. Email: lyon@docjava.com. Web: http://www.DocJava.com.

Caroline Neilson will complete her Bachelor of Science in computer science major at Fairfield University this May. She is a member of the Fairfield University Student Association(FUSA), and Chief Technology Officer for Right Hand Apprentice in the Fairfield StartUp Club. Upon graduation, Caroline will begin studying for a Master of Science degree in Computer Science at Georgetown University Graduate School of Arts & Sciences.