AC 2009-1192: EVALUATION OF ABET PROGRAM CURRICULA CRITERIA FOR THE INTEGRATION OF SUSTAINABILITY RELATED SUBJECT AREAS

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Abstract

ABET has also acknowledged the need for the integration of sustainability into engineering programs by including it in general criteria. A content analysis was performed on the criteria for each undergraduate program accredited by ABET. Sustainability and its component concepts of environment, society, and economy were identified within individual program criteria. As a relative measure of integration of sustainability into the program specific criteria, the number of individual programs containing reference to these concepts was compared to the number of programs referring to mathematics, a theme chosen because of its relevance to all engineering programs. All of these concepts were found with less frequency that the core subject area of mathematics. Sustainability was not specifically identified within any individual program criteria. Society was found within seven program criteria. Economy related concepts were found within five specific program criteria, while environment was identified within three. Despite the fact that much of the effort to develop sustainability related courses and teaching materials has been lead by environmental engineering programs and faculty, mining engineering was the only program criteria which specifically mentioned all three component concepts of sustainability.

Introduction

Recently, sustainability has evolved as a discipline in its own right. Universities have developed graduate programs where the focus of study centers on sustainability, such as master's programs at the Rochester Institute of Technology[1] and the University of Michigan[2]. However, institutions must not make the mistake of focusing upon the evolution of sustainability into a stand-alone discipline, while neglecting the integration of sustainability related classes and concepts into all programs of engineering. A compelling argument for the integration of sustainability into existing engineering disciplines is made by Kirby et al:

> "The future of sustainable design will highly depend on institutions of higher education incorporating green concepts into the curriculum. Academic institutions can contribute to the acceptance of sustainability in architectural and engineering design by offering courses and programs on the subject."[3]

ABET has also acknowledged the need for the integration of sustainability into engineering programs by including it in general criteria. Within the accreditation criteria effective for the 2008-2009 accreditation cycle, Criterion 3 (Program Outcomes) specifically addresses sustainability within all baccalaureate level programs. Criterion 3(c) states that engineering programs must demonstrate their students attain the following outcome:

> "an ability to design a system, component, or process to meet desired needs within realistic constraints, such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."[4]

Through these general Program Outcomes, ABET acknowledges the importance of considering sustainability within design. To do this, an understanding of the economic, environmental, and societal impacts (within sustainability, these impacts are often referred to as the Triple Bottom

Line, a phrase coined by John Elkington[5]) is necessary. Criterion 3(h) states that engineering programs must demonstrate that their students attain the following outcome:

> "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[4]

This criterion promotes the inclusion of component concepts of sustainability (environment, society, and economics) into all engineering programs. For sustainability to truly become another design constraint of modern day engineers, it must be effectively incorporated into all engineering programs. Students must understand the underlying concepts of the triple bottom line of sustainability (environment, society, and economy) so that they can meet the criterion 3(h) outcome of understanding the impact of engineering solutions within the context of these parameters, as well as the criterion 3(c) of designing a system within sustainability constraints. To address sustainability within design, students must be educated in the core concepts of sustainability (environment, economy, and society). The measure of the integration of these themes into program specific criteria can serve as a measure of each program's success at integrating sustainability content. Thus, the ABET program specific criteria for the 26 accredited programs was analyzed for the occurrence of sustainability, and its core concepts.

Methods

A content analysis was performed on the criteria for each undergraduate program accredited by ABET. Sustainability itself was identified as a key concept for analysis, and assigned an associated code tag of S_1. Additionally, core concepts within sustainability may also be covered individually within a program. As sustainability emphasizes the triple bottom line of environment, society, and economics, these three topics were also identified as key sustainability concepts for analysis (S_2, S_3, and S_4, respectively, shown in the table below). Key concepts related to the environment were those pertaining to environmental impacts and issues. The key concept of society included social impacts and issues, law, public policy, safety, and people. Key concepts related to economics were business, engineering economics, and cost-benefit analysis.

As sustainability, and its component topics, are specifically mentioned in 2008-2009 criterion 3(c, and h), describing the program outcomes required across all programs[4], it could be argued that sustainability need not be specifically detailed within individual program criteria. Thus, for comparison purposes, Mathematics was also identified as a key concept for analysis (and assigned the code M). Mathematics was used as a basis of comparison for the integration of fundamental concepts from general criteria into program specific criterion because it is a fundamental topic in all programs of engineering, and is identified in Criterion 3(a)[4].

The program content description within the 2008-2009 accreditation cycle[4] was then analyzed for the occurrence of the key concepts. Sections of text within an individual program criterion were identified as pertaining to one of the key concepts for analysis, and assigned the associated code for that concept.

Key concepts identified within program criteria and associated code	
Concept	**Code**
Sustainability	S_1
Environment: Environmental Impacts & Issues	S_2
Society: Social Impacts & Issues, Law & Public Policy, Safety, and People	S_3
Economics: Business, Engineering Economics, Cost-Benefit Analysis	S_4
Mathematics: Differential Equations, Calculus, Probability and Statistics	M

Results

The program specific criteria included no references to sustainability, S_1. However, its component subjects were identified within individual program criteria.

The second sustainability concept identified within the program criteria, S_2, encompassed the environment, or environmental impacts and issues. S_2 concepts were identified within three specific program criteria, including, environmental, geological, and mining engineering. Quotes of the actual environmental concepts tagged within each specific program criteria are provided in the appendix.

The third sustainability concept identified within the program criteria, S_3, encompassed topics pertaining to society, including social impacts and issues, law and public policy, safety, and people. S_3 concepts were identified within 7 individual program criteria, including civil engineering, construction engineering, environmental engineering, geological engineering, industrial engineering, mining engineering, engineering management, and similarly named engineering programs. Quotes of the actual society related concepts tagged within each specific program criteria are provided in the appendix.

The fourth sustainability concept identified within the program criteria, S_4, included topics pertaining to economics, such as business, engineering economics, cost-benefit analysis. S_4 concepts were identified within 5 individual program criteria, including architectural, civil, construction, mining, and petroleum engineering. Quotes of the actual economy related concepts tagged within each specific program criteria are provided in the appendix.

As a comparison, mathematics was specifically referenced within 19 of the 26 individual programs, as listed in the appendix.

Code Results for key concepts identified within program criteria		
Concept	**Code**	**Number of Occurrences**
Sustainability	S_1	0
Environment: Environmental Impacts & Issues	S_2	3
Society: Social Impacts & Issues, Law & Public Policy, Safety, and People	S_3	7
Economics: Business, Engineering Economics, Cost-Benefit Analysis	S_4	5
Mathematics: Differential Equations, Calculus, Probability and Statistics	M	19

Discussion

As sustainability, and its component topics, are specifically mentioned in 2008-2009 criterion 3(c, and h), describing the program outcomes required across all programs[4], it could be argued that sustainability need not be specifically detailed within individual program criteria. If this argument were valid, fundamental engineering concepts, such as mathematics, would not be mentioned within the program specific criteria. In fact, mathematics was specifically referenced within 19 of the 26 individual programs, representing integration into 73% of the program specific criteria. If the number of individual program criteria which mention a given concept is accepted as an indicator of the integration of that concept across the range of disciplines, sustainability as a whole is relatively not integrated, when compared to mathematics. Among component concepts of sustainability, environment related concepts are the least integrated across programs, and society related concepts as the most integrated of the sustainability related concepts.

Additionally, comparison of the programs in which the sustainability component concepts were identified is provided in the table below. Only one program's criteria specifically referenced all three component concept of sustainability: mining engineering.

Four programs' criterion contained two of the sustainability component concepts. Environment and society related concepts were tagged within both environmental and geological engineering programs. Society and Economy related concepts were tagged within both civil and construction engineering programs.

Four programs' criterion only mentioned one of the component concepts of sustainability. Society related concepts were tagged within both industrial engineering and engineering management. Economy related concepts were identified within both architectural and petroleum engineering programs.

Comparison of Code Results Across Various Programs X = code content was tagged within that specific program criteria				
Specific Program	**S_1 Sustainability**	**S_2 Environment**	**S_3 Society**	**S_4 Economy**
Architectural and Similarly Named Engineering Programs				X
Civil and Similarly Named Engineering Programs			X	X
Construction and Similarly Named Engineering Programs			X	X
Environmental and Similarly Named Engineering Programs		X	X	
Geological and Similarly Named Engineering Programs		X	X	
Industrial and Similarly Named Engineering Programs			X	
Mining and Similarly Named Engineering Programs		X	X	X
Engineering Management and Similarly Named Engineering Programs			X	
Petroleum and Similarly Named Engineering Programs				X

Criterion 3(c&h) include outcomes of designing a system within sustainability constraints and understanding the impact of engineering solutions. Despite these requirements, which should be applied to all programs, the overwhelming majority of engineering programs have failed to integrate the core concepts related to sustainability into program criteria.

Conclusion

A content analysis was performed on the criteria for each of the 26 undergraduate programs accredited by ABET. Sustainability and its component concepts of environment, society, and economy were identified within individual program criteria. Sustainability was not specifically identified within any individual program criteria. Society was found within seven program criteria. Economy related concepts were found within five specific program criteria, while environment was identified within three. All of these concepts were found with much less frequency that the core subject area of mathematics, which was identified within 19 programs. When compared to the fundamental engineering subject of mathematics, sustainability and its core concepts are relatively not integrated into specific program criteria. Despite the fact that much of the effort to develop sustainability related courses and teaching materials has been lead by environmental engineering programs and faculty, mining engineering was the only program criteria which specifically mentioned all three component concepts of sustainability.

Individual programs, as a whole, should look to the general program outcomes as guidelines for all engineering programs. It is clear that additional efforts are needed to ensure that each accredited program integrates the core concepts of sustainability into its criteria.

Bibliography

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Appendix

Code Results for S_2: Environment: Environmental Impacts & Issues	
Specific Program	**Concept as quoted from the Program Criteria**
Environmental and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…introductory level knowledge of environmental issues associated with air, land, and water systems…"[4]
Geological and Similarly Named Engineering Programs	"Engineering knowledge to design solutions to geological engineering problems, which will include one or more of the following considerations…impacts of construction projects; impacts of exploration, development, and extraction of resources, and consequential remediation; disposal of wastes…"[4]
Mining and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…proficiency in engineering topics related to both surface and underground mining, including…environmental issues…"[4]

Code Results for S_3: Society: Social Impacts & Issues, Law & Public Policy, Safety, and People	
Specific Program	**Concept as quoted from the Program Criteria**
Civil and Similarly Named Engineering Programs	"The program must demonstrate that graduates can…explain basic concepts in…public policy…"[4]
Construction and Similarly Named Engineering Programs	"The program must demonstrate the graduates have…and understanding of legal and professional practice issues related to the construction industry…and understanding of…safety, an understanding of management topics such as…law…"[4]
Environmental and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…introductory knowledge of environmental issues associated with air, land, and water systems and associated environmental health impacts; an ability to conduct laboratory experiments and to critically analyze and interpret data in more than one major environmental engineering focus areas, e.g.…environmental health…"[4]
Geological and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…engineering knowledge to design solutions to geological problem, which will include one or more of the following considerations…the impacts of… other activities of society on these (earth) materials and (surface and near-surface) processes…"[4]

Industrial and Similarly Named Engineering Programs	"The program must demonstrate that graduates have the ability to design, develop, implement, and improve integrated systems that include people…"[4]
Mining and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…proficiency in engineering topics related to both surface and underground mining, including…health and safety"[4]
Engineering Management and Similarly Named Engineering Programs	"The program must demonstrate that graduates have: an understanding of…the human element in production, research, and service organizations…"[4]

Code Results for S_4: Economy: Business, Engineering Economics, Cost-Benefit Analysis	
Specific Program	**Concept as quoted from the Program Criteria**
Architectural and Similarly Named Engineering Programs	"The program must demonstrate that graduates have: proficiency in…engineering economics…"[4]
Civil and Similarly Named Engineering Programs	"The program must demonstrate that graduates can…explain basic concepts in…business…"[4]
Construction and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…an understanding of construction…cost, accounting,…engineering economics,…and cost engineering."[4]
Mining and Similarly Named Engineering Programs	"The program must demonstrate that graduates have…proficiency in engineering topics related to both surface and underground mining, including…valuation and resource/reserve estimation…"[4]
Petroleum and Similarly Named Engineering Programs	"The program must demonstrate that graduates have competency in…use of project economics and resource valuation methods for design and decision making under conditions of risk and uncertainty. "[4]

Mathematics, including calculus, differential equations, statistics, and/or probability, were detailed within the 19 of the 26 program criteria provided in the 2008-2009 criteria for accreditation[4], including the following programs:

1. Agricultural and Similarly Named Engineering Programs
2. Architectural and Similarly Named Engineering Programs
3. Bioengineering and Biomedical and Similarly Named Engineering Programs
4. Biological and Similarly Named Engineering Programs
5. Civil and Similarly Named Engineering Programs
6. Construction and Similarly Named Engineering Programs
7. Electrical, Computer and Similarly Named Engineering Programs
8. Engineering Mechanics and Similarly Named Engineering Programs

9. Environmental and Similarly Named Engineering Programs
10. Geological and Similarly Named Engineering Programs
11. Industrial and Similarly Named Engineering Programs
12. Materials, Metallurgical and Similarly Named Engineering Programs
13. Mechanical and Similarly Named Engineering Programs
14. Mining and Similarly Named Engineering Programs
15. Naval Architecture, Marine Engineering, and Similarly Named Engineering Programs
16. Nuclear, Radiological, and Similarly Named Engineering Programs
17. Ocean and Similarly Named Engineering Programs
18. Petroleum and Similarly Named Engineering Programs
19. Software and Similarly Named Engineering Programs